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Pre-restoration characteristics of upper Willow Creek Granite County Montana.

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Pre-Restoration Characteristics of Upper Willow Creek, Granite County, Montana

by

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Pre-Restoration Characteristics of Upper Willow Creek,
Granite County, Montana

Chair: Vicki Watson VW

Listed as "impaired" on the Montana Department of Environmental Quality 303(d) list in 1996, 2000 and 2002, Upper Willow Creek falls in the "not supporting" category for aquatic life and cold-water fisheries due to habitat degradation and lack of flow. Montana Fish, Wildlife and Parks identified Upper Willow Creek as a high priority tributary of Rock Creek for restoration of westslope cutthroat trout (*Oncorhynchus clarki lewisi*) and bull trout (*Salvelinus confluentus*) habitat. Physical, chemical and biological aspects of Upper Willow Creek were studied to document current conditions and identify sources of impairment and restoration needs. Biological descriptions involved conducting instream habitat and riparian vegetation surveys and sampling fish populations. The physical assessment documented substrate composition, channel morphology, temperature fluctuations and discharge. The chemical component of the study addressed nutrient and sediment levels at five sample locations throughout the length of Upper Willow Creek. The upper 9.5 miles (section I) of the creek showed excellent aquatic habitat quality, healthy riparian vegetation, high trout densities and stable channel conditions. The middle 5.8 miles (section II) showed poor riparian vegetation and multiple channel alterations, degraded aquatic habitat and elevated water temperatures. The lower 6 miles (section III) showed few channel alterations and fair riparian and instream habitat quality; however, problems were evident including high water temperature and fine sediment accumulation due to disturbances in section II. Suspended sediments were low in this low flow year; however, nutrient concentrations exceeded water quality standards adopted by the State of Montana for the Upper Clark Fork River.

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Acknowledgements

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Introduction

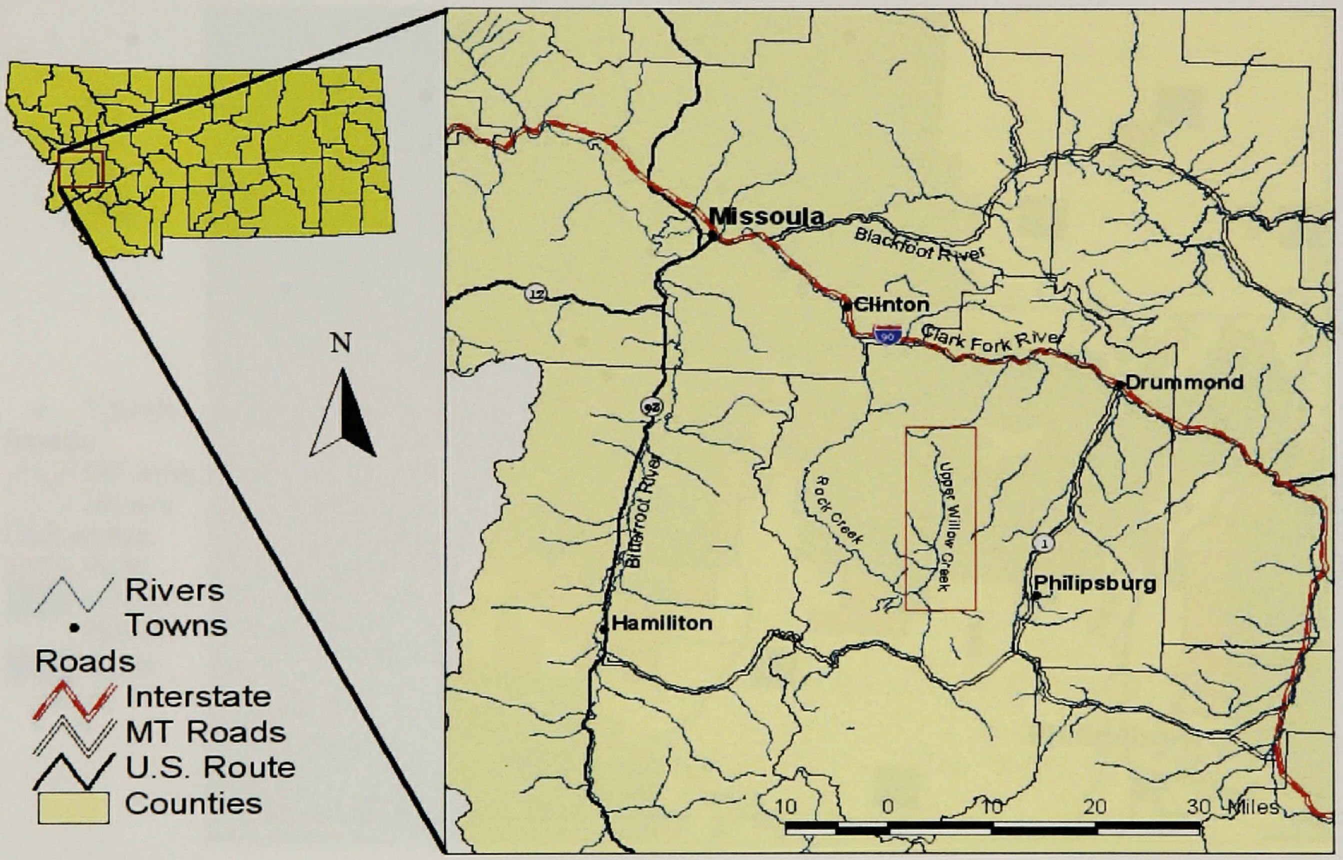
The natural functions of riparian and stream ecosystems are essential in sustaining agricultural resources, fish and wildlife habitat and water quality. In the Western United States, riparian habitat occupies only 2% of the landscape, although its importance far outweighs its relatively small area (Hansen et al. 1995; Patten 1998). Because riparian areas provide water, forage and habitat, they receive extensive use from humans, livestock and wildlife. Conflicting uses such as recreation, grazing, agriculture, forestry, mining and wildlife often compete for these productive areas.

Land-use strategies can significantly alter the hydrologic structure and function of a stream. Stream channelization and removal of bank vegetation are common practices to maximize potential grazing and hay production. Significant changes in channel morphology and vegetation over prolonged periods can influence water quality and the biological integrity of downstream reaches (Sanborn et al. 1998). Fish populations may also be influenced, as spawning and rearing habitats and aquatic insect populations are often degraded as a result of these practices (Wydoski and Helm 1980; von Guerard 1989; Crouse et al. 1981). Impacts from multiple uses have significantly influenced the nature of many stream ecosystems. As a result, careful management and restoration of riparian zones and stream channels is important to slow and reverse degradation of aquatic resources. Proper management can provide benefits to agricultural and recreational uses while ensuring healthy streams. Such benefits include protection from floods and droughts by natural storage of water in floodplains, increased water and vegetation quality and quantity, livestock shelter and fisheries and wildlife use.

Study Area

Upper Willow Creek near Philipsburg, Montana, has been heavily impacted by multiple uses over the last century. Originating in the John Long Mountains, the creek flows south approximately 21 miles to its confluence with Rock Creek, a tributary of the Clark Fork of the Columbia River (Figure 1).

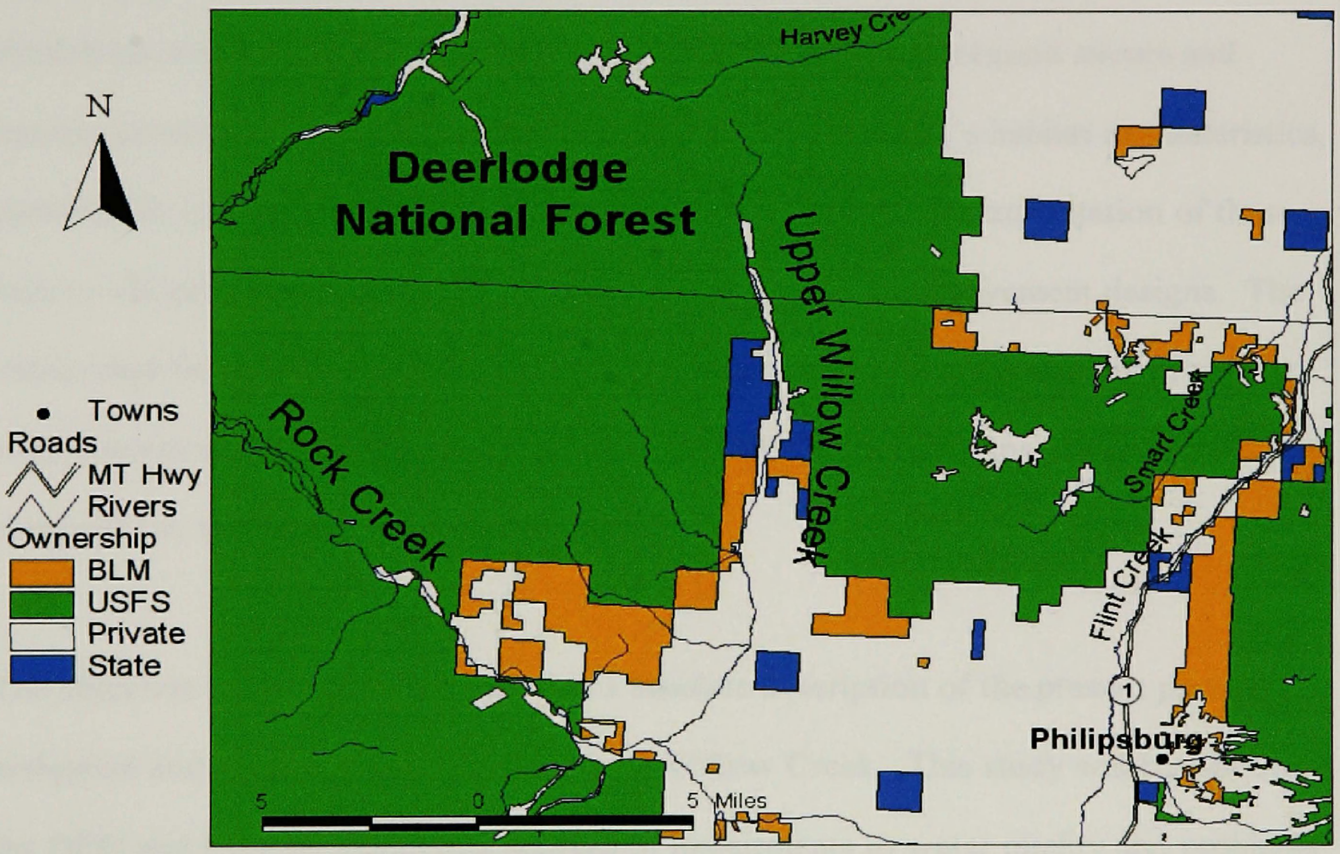
Figure 1 – Location of Upper Willow Creek



Although headwater reaches are in the Beaverhead-Deerlodge National Forest, the majority of the creek (85%) flows through private homesteads, ranches and subdivided lots (Figure 2). Land use within the 95 mi^2 watershed includes forest, rangeland, flood irrigated hay land and recreation. Cow-calf and haying operations comprise the primary agricultural uses. Multiple bridges along the creek offer public access for anglers. Upper

Willow Creek provides critical habitat for native trout species, including westslope cutthroat (*Onchorynchus clarkii lewisii*), a state species of special concern, and bull trout (*Salvelinus confluentus*), federally listed as "threatened". Upper Willow Creek is a major tributary of Rock Creek, and provides both spawning and juvenile rearing habitat for these two salmonids (Carnefix 2002; Swanberg 1996).

Figure 2 – Land Ownership of Upper Willow Creek



Problem to be Addressed

The Montana Department of Environmental Quality (DEQ) listed Upper Willow Creek as "impaired" on its 2002 303(d) list of water bodies due to habitat alterations and dewatering. Under the Clean Water Act, the state of Montana is required to assess all impaired water bodies and develop any necessary water quality restoration plans. Montana Fish, Wildlife and Parks (FWP) is interested in restoring degraded reaches of

Upper Willow Creek to re-establish bank stabilizing vegetation, fish habitat, channel dimension and natural fluvial patterns. These efforts are an attempt to restore the stream's hydrologic, geomorphic and biologic processes through construction of a stable floodplain and channel, natural habitat improvement and erosion control structures and revegetating a riparian corridor. It is unlikely Upper Willow Creek can be restored to a pre-European settlement condition, as this would include reintroducing beavers and eliminating water withdraws. A detailed description of pre-restoration stream and riparian conditions is needed to document Upper Willow Creek's habitat characteristics, geomorphic pattern, biologic composition and water quality. Documentation of these factors will prioritize restoration needs and assist in habitat improvement designs. The results may be comparable with post-restoration monitoring surveys showing the effectiveness of restoration on habitat improvement, fish populations, substrate composition, temperature, and water quality.

The objective of this study is to provide a baseline description of the present physical, biological and chemical conditions in Upper Willow Creek. This study will benefit both the DEQ and FWP by identifying sources of impairments to water quality and problems that may limit the salmonid fishery in Upper Willow Creek.

Methods

Baseline biological descriptions of Upper Willow Creek involved conducting an instream habitat and riparian vegetation survey and sampling fish populations. The physical assessment involved documenting substrate composition, channel morphology, temperature fluctuations and discharge. The chemical component of the study addressed nutrient and sediment loads at five sample locations throughout the length of Upper Willow Creek.

Riparian Habitat Inventory

The condition of riparian habitat along Upper Willow Creek was inventoried using the Riparian and Wetland Research Program's (RWRP) short lotic health form (Hansen et al. 2000) (Appendix A). The RWRP procedure divides a creek's riparian habitat into "polygons" or areas of similar characteristics and management plans. Upper Willow Creek was divided into 15 polygons to inventory riparian health based on private land boundaries and separately managed areas throughout the basin (Figure 3).

Health or condition was based on scores given for the following factors:

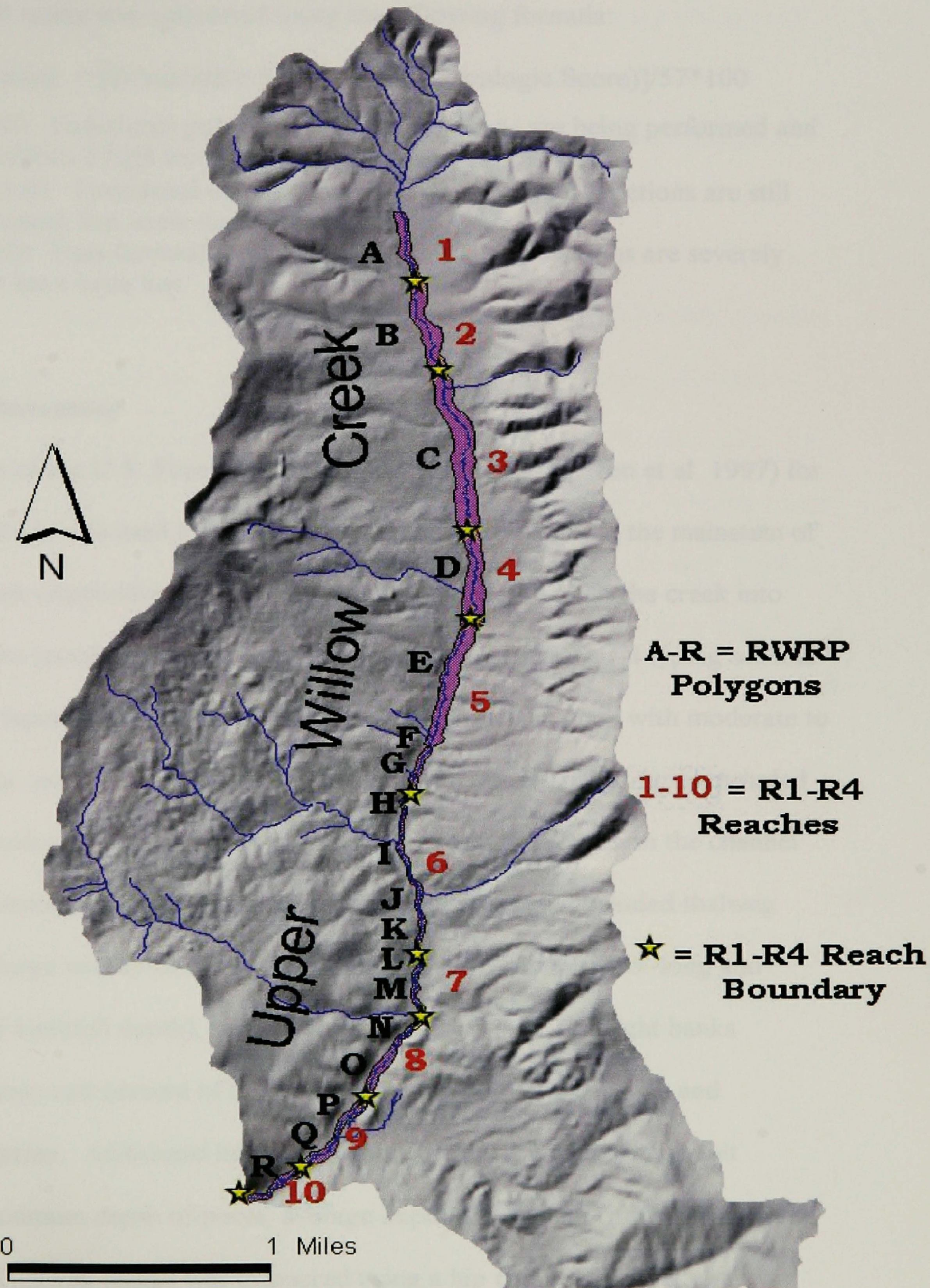
<u>Vegetative Characteristics</u>

- Vegetative cover of floodplain and streambanks
- Invasive plant species
- Disturbance-increaser/undesirable herbaceous species
- Preferred tree and shrub establishment and regeneration
- Utilization of preferred trees and shrubs
- Standing decadent and dead woody material

<u>Soil/Hydrologic Characteristics</u>

- Streambank root mass protection
- Human-caused bare ground
- Streambank structurally altered by human activity
- Presence of pugging and/or hummocking
- Stream channel incisement (vertical stability)

Figure 3 –Upper Willow Creek RWRP Polygons A-R and R1-R4 Reaches 1-10



Each polygon's scores for the above factors were tallied to give an overview of riparian health. The RWRP rating was calculated using the following formula:

$$\text{RWRP Rating} = [(\text{Vegetative Score})+(\text{Soil/Hydrologic Score})]/57*100$$

- Rating = >80: Functional polygon. Riparian functions are being performed and the reach exhibits a high level of riparian condition.
- Rating = 60-80: Functional-at-risk polygon. Many riparian functions are still being performed, but some signs of stress are apparent.
- Rating = <60: Non-functional polygon. Most riparian functions are severely impaired or have been lost.

Aquatic Habitat Inventory

A modified version of the U.S. Forest Service R1-R4 protocol (Overton et al. 1997) for aquatic habitat analysis was used to inventory the aquatic habitat along the mainstem of Upper Willow Creek (Appendix C). This procedure involved dividing the creek into discrete habitat units (pools, runs, and riffles) and applying a hierarchical typing scheme. Fast water habitat types including riffles and runs were defined as units with moderate to fast current velocity, generally greater than 1 ft/sec. Slow water habitat types included pools in which scouring water has carved out a non-uniform depression in the channel bed or has been dammed. Parameters measured in all habitat units included thalweg length, number of large woody debris items (defined as >6" diameter, >6' long and presence below the bankfull depth), percent bank stability on left and right banks (looking downstream) and percent of bank coverage in woody, herbaceous and regenerating vegetation. Additional habitat data collected every fifth habitat unit included width, maximum depth of pools, average depth of runs and riffles and percent undercut banks. Thalweg length was measured using a hip chain, which fed biodegradable string through an odometer. Width, maximum depth of pools and average depths of riffles and runs were measured in tenths of feet using a staff rod. Visually estimated parameters included percent bank stability of left and right banks and percent woody, herbaceous and regenerating woody vegetation. Upper Willow Creek was divided into ten R1-R4 reaches based on major landowners within the basin (Figure 3).

Fish Population Estimates

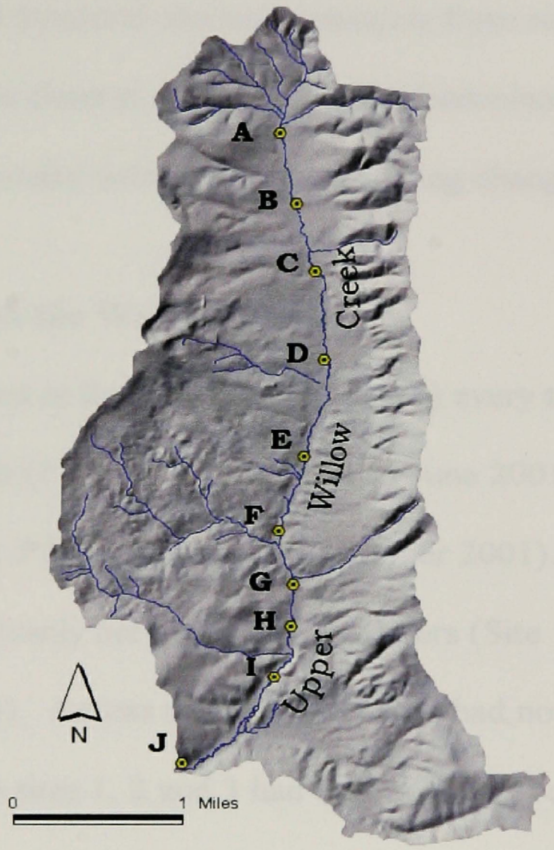
Fish were sampled at seven reaches (Figure 4) using a backpack electroshocker. Sample locations were chosen to determine several population estimates upstream, throughout and downstream of a proposed restoration project reach. Three-pass removal estimates were calculated for each sample reach. Water temperature, GPS location, species, length, weight and presence of any markers (fin clips, tags, etc) were recorded for each reach. Reaches 2, 4, 6 and 7 were sampled on 18 and 19 July 2001. Reaches 3 and 5 were sampled 18 September 2001. Reach 1 was sampled 4 November 2001. Average width and total length of each reach was recorded for density estimates.

Figure 4 – Upper Willow Creek Electrofishing Reaches 1-7

Substrate Composition

The Wolman pebble count procedure (Wolman 1954; Potyondy and Hardy 1994; Kondolf 1997) was used to characterize the substrate of Upper Willow Creek at ten sites (Figure 5). These sample locations were spaced throughout the creek at approximately two-mile intervals. Substrate particle sizes were recorded for adjacent pools and riffles at each sample site. The intermediate axis (B-axis) of particles was measured using a ruler. Particles were classified into grain size classes including silt/clay (<0.62mm), sand (0.62 – 2mm), gravel (2 – 64mm), cobble (64 – 256mm), boulder (256 – 2048mm) and bedrock (>2048mm). Median particle size for each sample site was determined by calculating the number of particles smaller than a given size class and graphing results on a log-linear chart.

Figure 5 – Upper Willow Creek Substrate and Cross-Section Sample Sites A-J



Channel Morphology

Channel cross sections were measured at the same ten locations (A-J) that pebble counts were recorded (Figure 5). Cross section data were recorded for an adjacent pool and riffle at each site. A tape was secured across the channel at bankfull level, establishing channel width. An Autotech 350 laser-level was used to measure bankfull depths at approximately 20 intervals across the channel. Width/depth ratios were calculated by dividing bankfull width by the average channel depth at bankfull level.

Upper Willow Creek sinuosity within each R1-R4 reach was determined using aerial photos taken on 18 May 2001 (1:3600 scale, 17.6 inches/mile). Values were calculated by dividing the stream length by the valley length. Sinuosity was calculated for reaches exhibiting the appearance of a natural channel separately from reaches with obvious channel alterations. Obvious channel alterations were determined using aerial photos and noting visual changes in sinuosity without a corresponding change in valley slope.

Nutrients and Sediments in the Water Column

Water samples were collected at five locations (Figure 6) every two weeks during the rising and falling hydrograph (17 May, 28 May and 19 June 2001), and once per month thereafter (28 June, 26 July, 5 September and 10 October 2001). An attempt was made to space the sample locations evenly between the headwaters (Site 1) and the mouth of Upper Willow Creek (Site 5). Access to all private lands had not been secured at the time of initial sampling, therefore sites 1, 2 and 3 had longer stream reaches between them than sites 3, 4 and 5. It is important to note only one discharge measurement and set of water samples were taken at each site per sample date. Therefore, no confidence intervals can be placed on discharge, sediment and nutrient concentrations and loads at a sample site. In order to compare sample sites or sample dates statistically, several samples at each of a range of flows would be necessary. This study attempted to give a general indication of the sediment and nutrient content of Upper Willow Creek throughout the rising and falling hydrograph of a single year before restoration efforts commenced.

Total suspended sediment samples were taken at various depths across the channel using a USGS suspended sediment sampler. To estimate suspended sediment load, discharge was also recorded during sampling. A tape measure was secured across the channel to record water depth and velocity at 0.5 meter intervals. Water velocity was measured at 60% of total depth using a Pygmy current meter on 17 May 2001, and a Marsh McBierney current meter on all other sample dates. The Marsh McBierney current meter was calibrated prior to initial discharge sampling.

Water samples were collected as grab samples in the thalweg. Sample bottles were rinsed with stream water and filled by raising and lowering the uncapped bottle from the top to the bottom of the water column until the bottle was full. Water samples for kjeldahl nitrogen, nitrates/nitrites and total phosphorous were placed in 250ml acid-washed bottles with 10ml concentrated sulfuric acid. Samples for ortho-phosphates were filtered through 0.45micron membrane filters with a glass fiber prefilter into 100ml acid-washed bottles. Samples were kept on ice or refrigerated until analyzed within two days of collection. Samples were analyzed by an EPA certified lab (Energy Labs, Inc., Box 5688 Helena, MT USA) for total suspended sediment (mg/l), total kjeldahl nitrogen (mg/l), nitrates and nitrites (mg/l), ortho-phosphates (mg/l) and total phosphorous (mg/l) (Table 1). Total N was calculated by adding total kjeldahl N and nitrates and nitrites.

Figure 6 – Upper Willow Creek Water Quality and Temperature Sample Locations 1-5

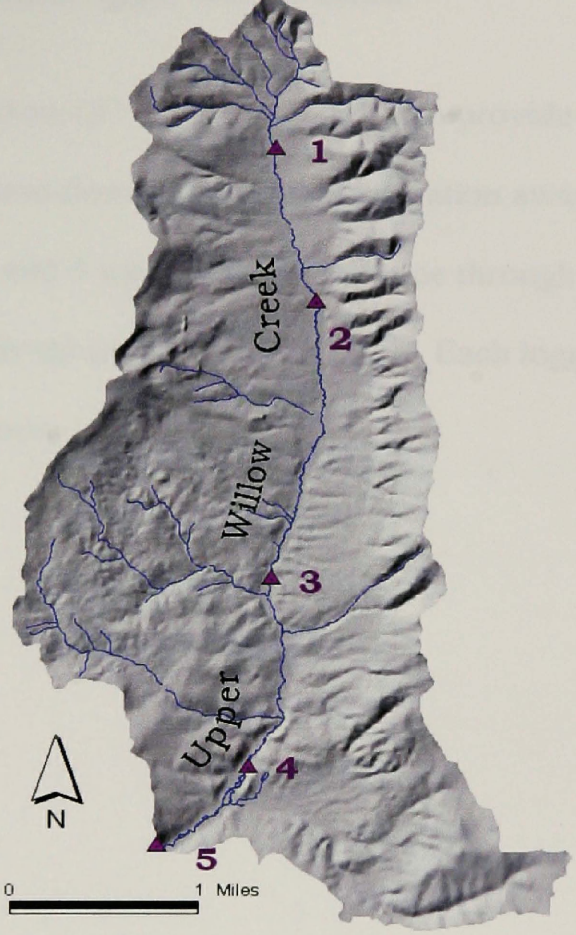


Table 1 – Energy Labs, Inc. Methods and Detection Limits

Result	Detection Limit	Method
Nitrogen, Total Kjeldahl	0.1 mg/l	EPA 351.3
Nitrogen, Nitrate + Nitrite	0.01 mg/l	EPA 353.2
Phosphate, Ortho	0.01 mg/l	EPA 365.1
Phosphorous, Total	0.01 mg/l	EPA 365.1
Total Suspended Sediment	10 mg/l	EPA 160.2

Temperature

Five "StowAway Tidbit" temperature data loggers (Onset Computer Corporation, Bourne, MA USA) were placed at five locations in Upper Willow Creek (Figure 6) to record daily temperature fluctuations. Deerlodge National Forest personnel placed loggers 1 and 5 as part of an ongoing research project. Additional loggers (2, 3 and 4) were deployed using USDA protocol (Chandler et al. 2002) to further understand surface water temperature patterns of Upper Willow Creek.

Each logger was wired to an 18" hollow metal pipe to provide an anchor. The pipes were secured well below the base-flow water level in a location away from direct sunlight. Forest Service loggers 1 and 5 were deployed 21 June through 2 October 2001. Loggers 2-4 were deployed 11 July through 9 October 2001. Each logger recorded water temperature every 1.5 hours.

Results

RWRP Riparian Inventory

Table 2 illustrates the configuration of RWRP polygons and R1-R4 reaches of Upper Willow Creek. Although some R1-R4 reaches contained only one RWRP polygon, other reaches were divided into multiple polygons due to physical boundaries (fences, roads, bridges etc.).

Table 2 – Upper Willow Creek R1-R4 Reaches and RWRP Polygons

Stream Mile	R1-R4 Reach	RWRP Polygon	Vegetative (27 poss)	Soil/ Hydrologic (30 poss)	Total (57 poss)	Score = Total/57*100	Rating
0.0 to 1.4	1	A	23	28	51	89	Functional
1.4 to 3.1	2	B	24	28	52	91	Functional
3.1 to 6.7	3	C	22	27	49	86	Functional
6.7 to 9.5	4	D	23	25	48	84	Functional
9.5 to 11.2	5	E	15	16	31	54	Non-Functional
		F	21	23	44	77	Functional-at-risk
		G	14	17	31	54	Non-Functional
11.2 to 13.9	6	H	22	28	50	88	Functional
		I	15	14	29	51	Non-Functional
		J	12	13	25	44	Non-Functional
		K	10	13	23	40	Non-Functional
13.9 to 15.7	7	L	11	15	26	46	Non-Functional
		M	13	17	30	53	Non-Functional
		N	13	16	29	51	Non-Functional
15.7 to 17.2	8	O	20	27	47	82	Functional
17.2 to 19.5	9	P	16	18	34	60	Non-Functional
		Q	18	24	42	74	Functional-at-risk
19.5 to 21.3	10	R	18	22	40	70	Functional-at-risk

Six polygons (A through D, H and O) had an RWRP rating of 80 or higher and were considered properly functioning. Three polygons (F, Q and R) had an RWRP rating between 60 and 80 and were considered functional-at-risk. Nine polygons (E, G, I-N and P) had an RWRP rating below 60 and were considered non-functioning.

Polygons exhibiting non-functional ratings (<60) showed low scores in both vegetative and soil/hydrologic categories (Figure 7). Overall, Upper Willow Creek riparian health scored highest in upstream reaches (A-D), lowest in mid reaches (E-N) and fair health in lower reaches (O-R) (Figure 8).

Figure 7 – RWRP Polygon Vegetative, Soil/Hydrologic and Total Scores for Upper Willow Creek

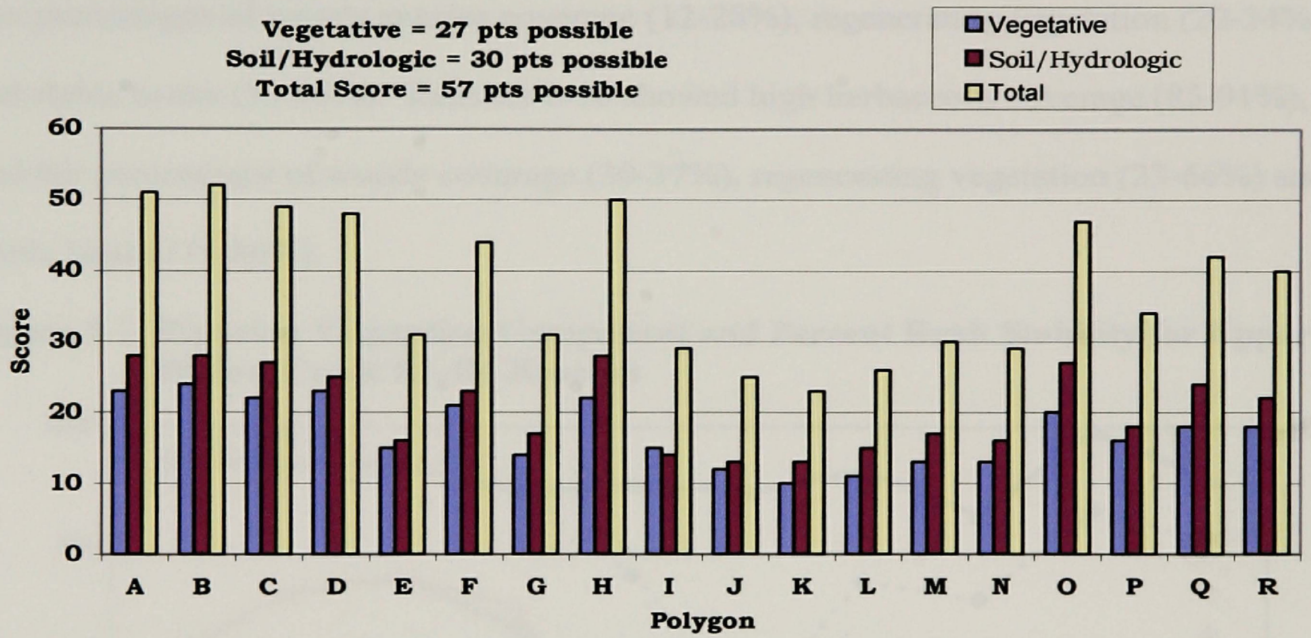
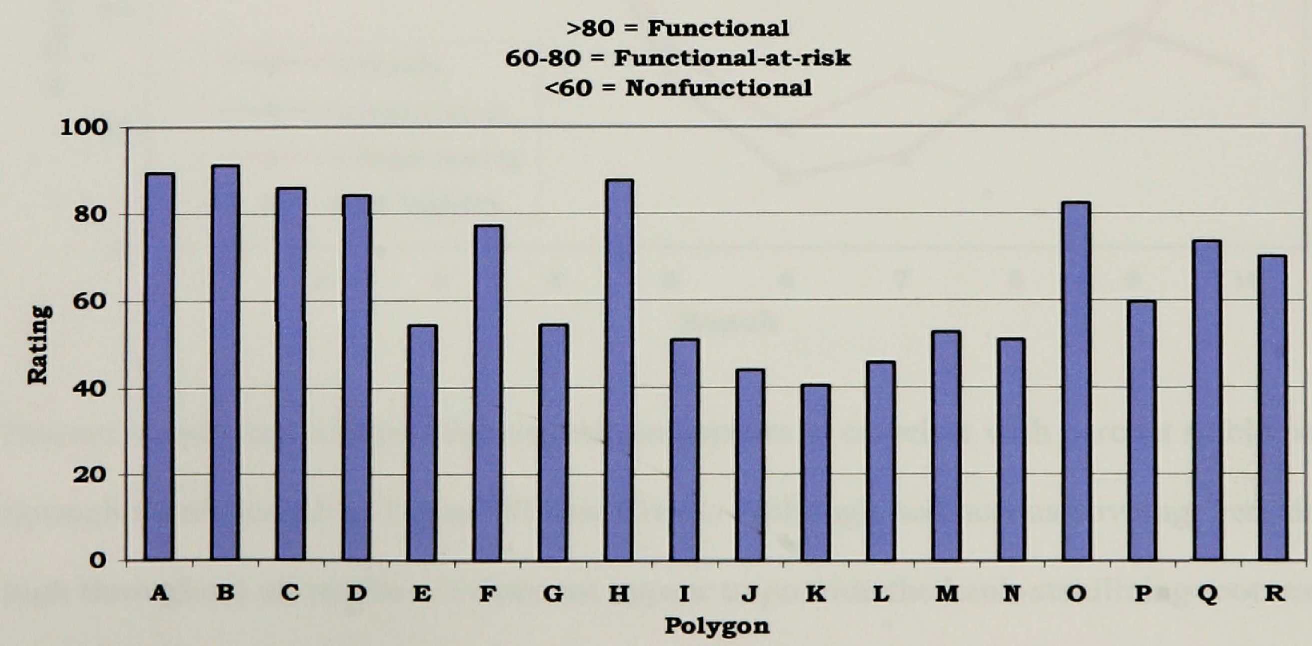


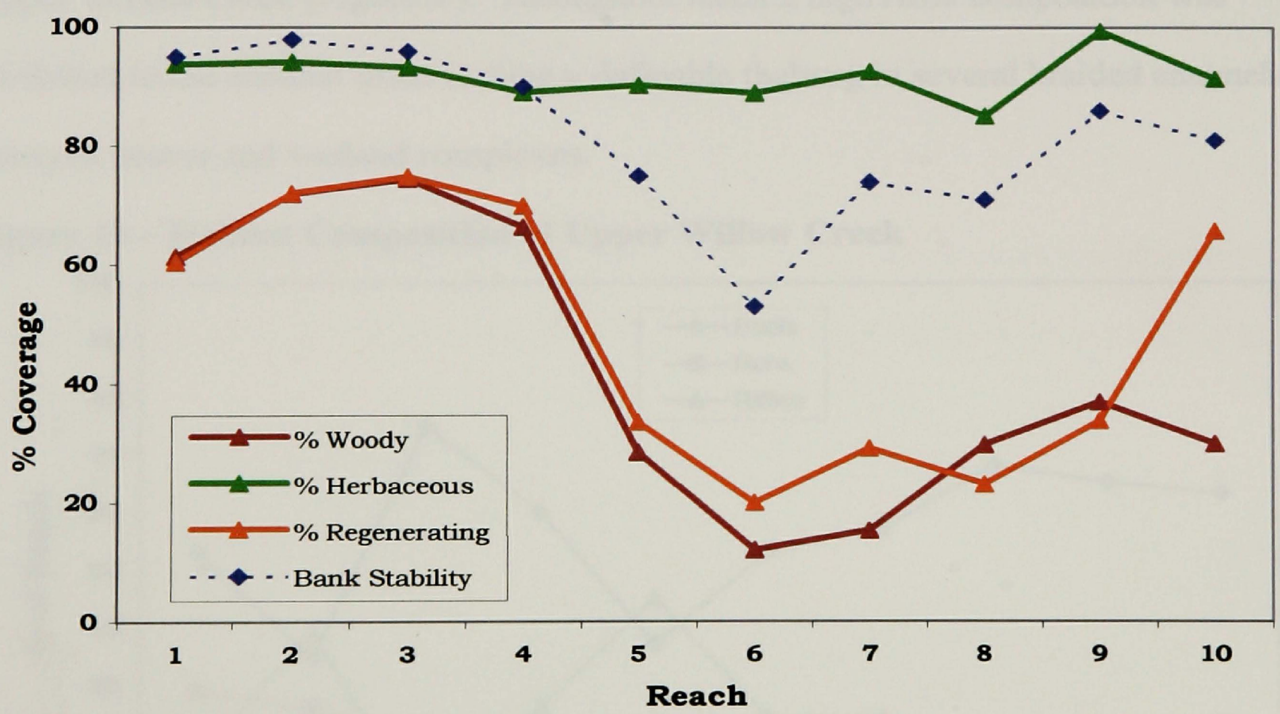
Figure 8 – RWRP Polygon Health Ratings for Upper Willow Creek



R1-R4 Instream Habitat Inventory

Results from the R1-R4 inventory indicated variability for percent stable banks and vegetation coverage (Figure 9). Reaches 1-4 had high percentages of herbaceous cover (85-99%), woody species cover (61-74%), regenerating vegetation (60-75%) and percent stable banks (90-98%). Reaches 5-7 also had high herbaceous coverage (89-93%) but low percentages of woody species coverage (12-28%), regenerating vegetation (20-34%) and stable banks (53-75%). Reaches 8-10 showed high herbaceous coverage (85-91%), and fair percentages of woody coverage (30-37%), regenerating vegetation (23-66%) and stable banks (71-86%).

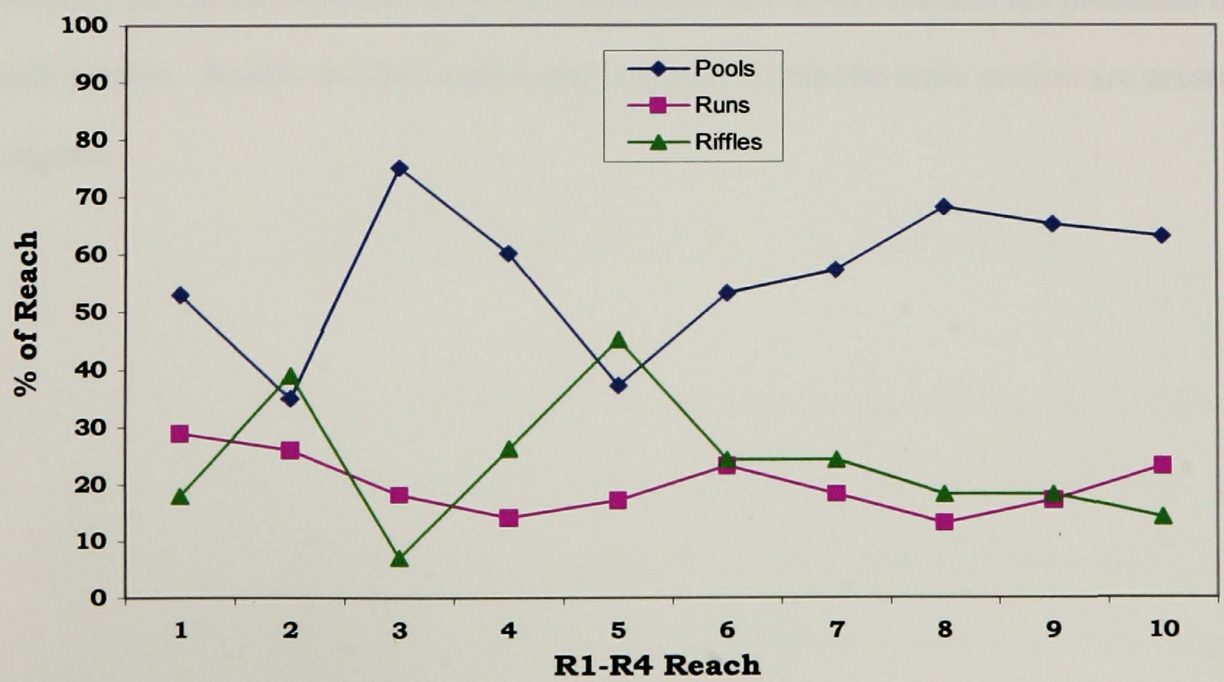
Figure 9 – Riparian Vegetation Component and Percent Bank Stability for Upper Willow Creek R1-R4 Reaches



Percent woody and regenerating vegetation appears to correlate with percent stable banks throughout the length of Upper Willow Creek. Although herbaceous coverage remains high throughout all reaches, it does not appear to provide the bank-stabilizing root mass capable of preventing banks from failing in reaches 5-8. The majority of woody species including willow, alder, chokecherry, woods rose and snowberry apparent in reaches 1-4 have either been heavily grazed or removed by chemical and physical means. The former landowner in reach 6 poisoned the riparian zone annually to provide increased grass and forb production (Bohrnsen 2001). Reaches 8-10 exhibited higher percent coverages of woody and regenerating species than reaches 5-7, as well as improved bank stability percentages. Although riparian shrubs appeared moderately grazed, most willows were mature and provided good bank-stabilizing root mass.

Habitat composition (pools, runs and riffles) varied throughout R1-R4 reaches 1-10 of Upper Willow Creek (Figure10). Throughout reach 2 high riffle composition was attributed to the channel often lacking a definable thalweg in several braided channels between beaver and wetland complexes.

Figure 10 – Habitat Composition of Upper Willow Creek



Reaches 5, 6 and 7 had lower percent pools due to alterations in channel morphology and riparian vegetation. Predominately natural sinuosity patterns in reaches 8, 9, and 10 caused pool composition to increase and riffle composition to decrease from reaches 5, 6 and 7.

Based on the RWRP and R1-R4 surveys, Upper Willow Creek was divided into three major sections. Section I begins at the most upstream boundary of R1-R4 Reach 1, extending 9.5 miles downstream to the lower boundary of R1-R4 reach 4. This section covers RWRP polygons A-D and R1-R4 reaches 1-4. Section II extends from stream mile 9.5 to stream mile 15.7, covering RWRP polygons E-N and R1-R4 reaches 5-7. Section III extends from stream mile 15.7 to stream mile 21.3 and covers RWRP polygons O-R and R1-R4 reaches 8-10.

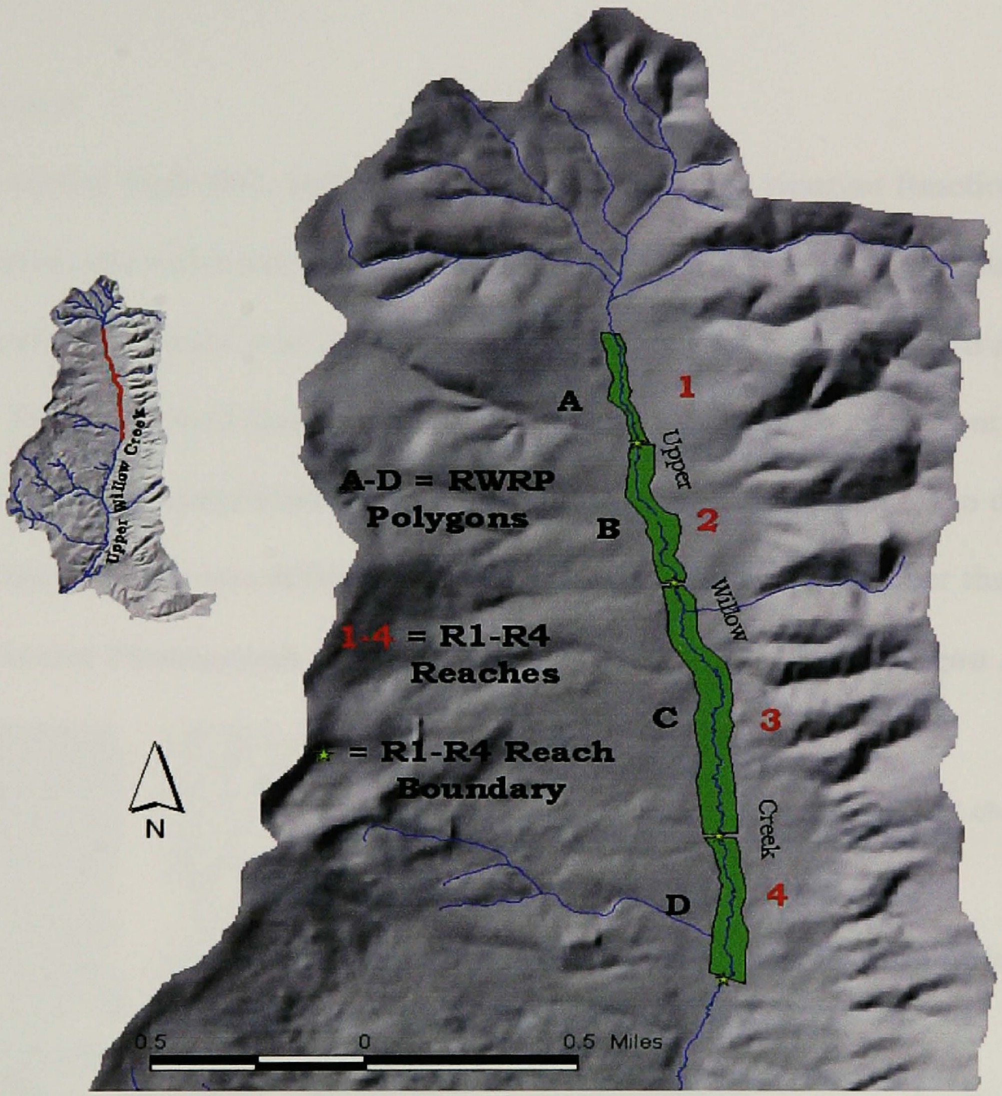
Habitat Descriptions

Detailed habitat descriptions for RWRP polygons and R1-R4 reaches are presented for each section. Results for the reaches and polygons within the same section are presented together.

Upper Willow Creek Section I

Section I included R1-R4 reaches 1-4 and RWRP Polygons A-D (Figure 11).

Figure 11 - Upper Willow Creek Section I



Reach 1 (Figure 11 and 12) extended 7,373 feet between stream mile 0.0 (Shylo Creek) and stream mile 1.4 and included RWRP polygon A. This reach showed high bank stability (95%) and woody composition (61%). Pool/riffle ratios were lower in this reach compared to downstream reaches due to natural morphological conditions of the channel. Most pools were formed by willow root masses and meander scours (41% and 36%,

respectively). Beaver dams accounted for 19% of pool formations. Maximum pool depth (1.9 ft) and mean water depth (0.7 ft) provide adequate habitat for fish. This reach had no evidence of physical channel alteration.

RWRP Polygon A

This polygon scored high (89), indicating it is providing most riparian functions at a high level. Vegetative and soil/hydrologic scores suggested good conditions. Grazing pressure on preferred shrubs was light, and only short lengths were trampled and sheared by livestock. Exotic spotted knapweed (*Centaurea biebersteinii*) was present at the downstream boundary where Forest Service Road 88 crosses the creek. The downstream boundary of this polygon was defined by a series of culverts passing under the road.

Figure 12 – Aerial Photograph over R1-R4 Reach 1 and RWRP Polygon A

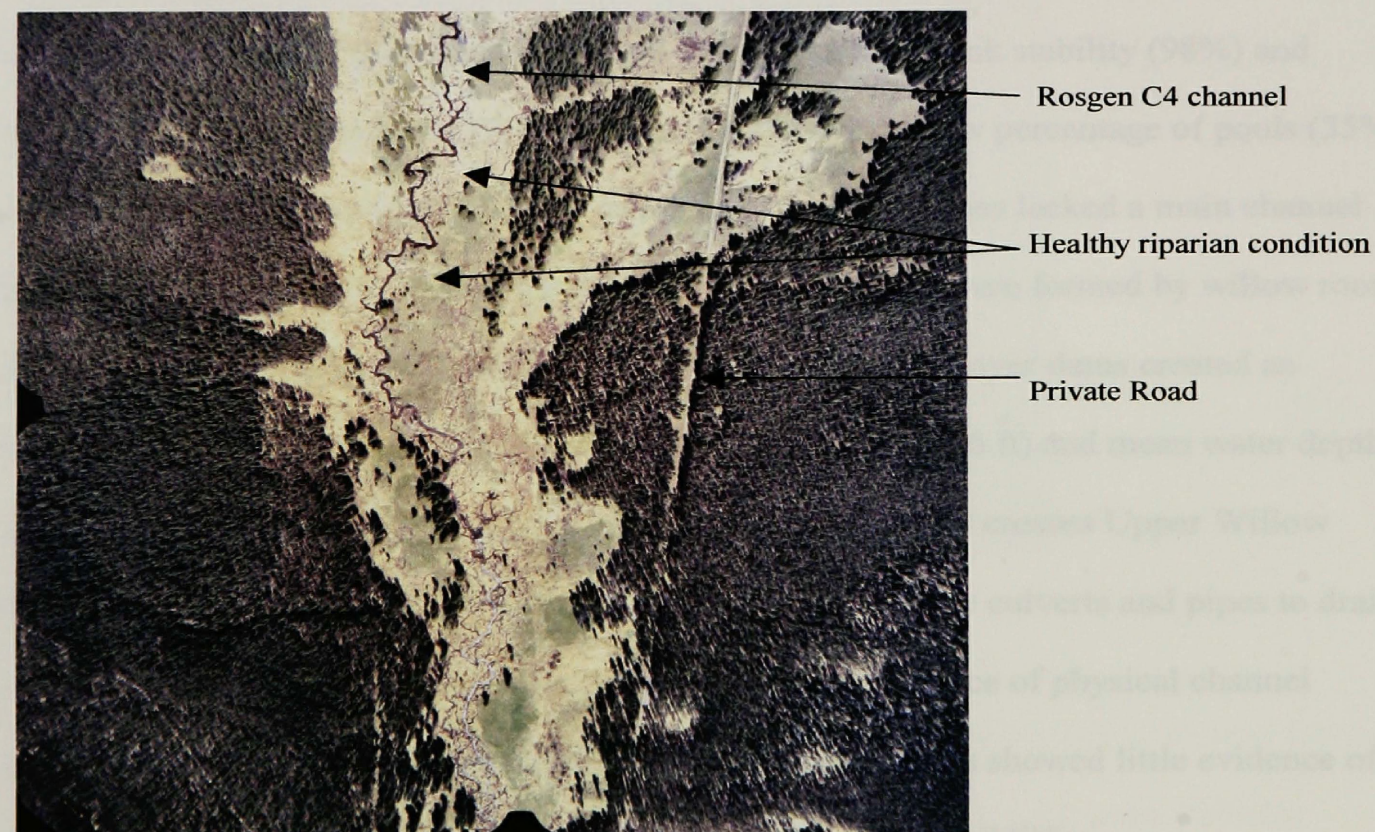


Figure 13 – Upstream boundary of R1-R4 reach 1 and RWRP Polygon A

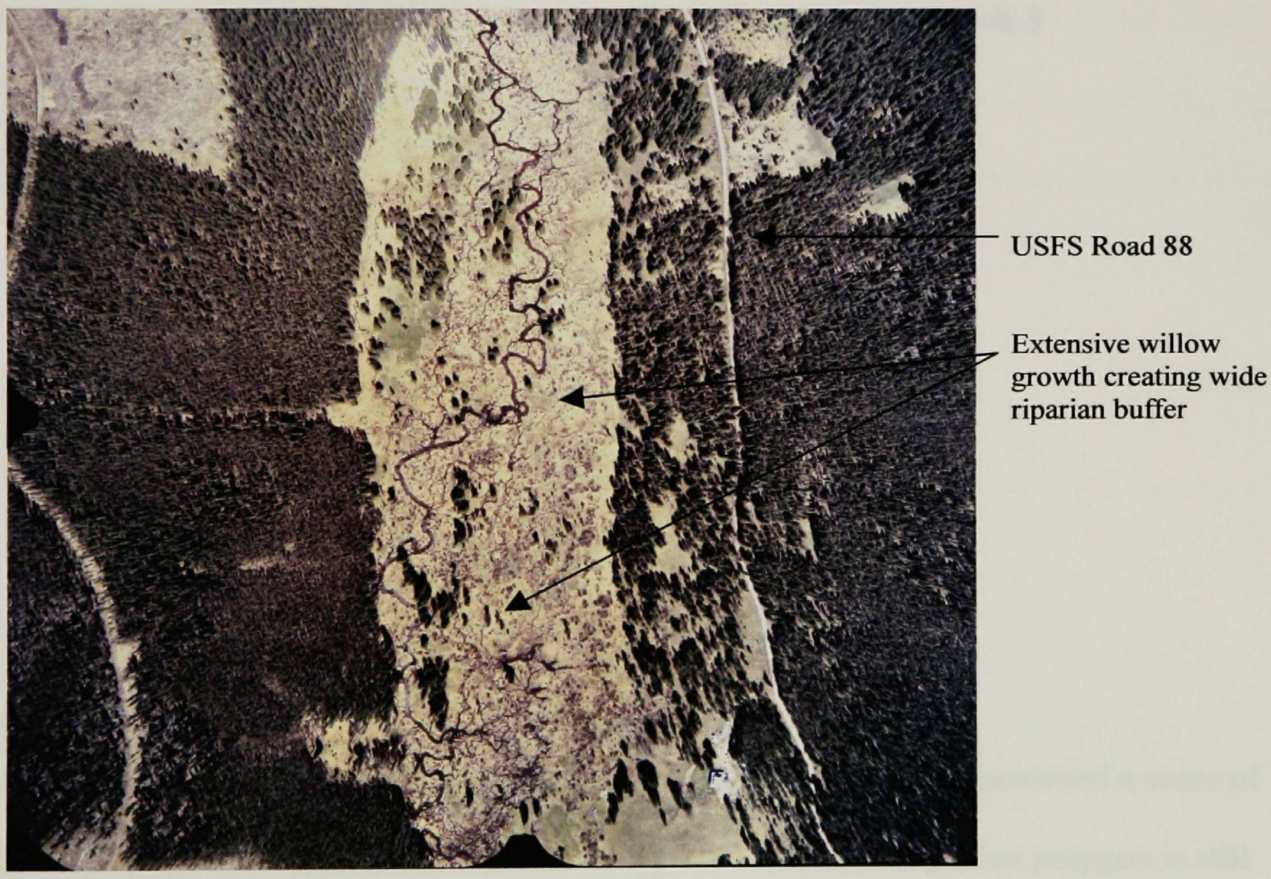
R1-R4 Inventory – Reach 2

Reach 2 extended 8,918 feet (stream mile 1.4 to 3.1, south border of McGeorge property) and contained RWRP polygon B. This reach showed high bank stability (98%) and woody species composition (72%). The creek contained a low percentage of pools (35%) due to many long stretches of braided channels. These stretches lacked a main channel and were classified as riffles during the survey. Most pools were formed by willow root masses and meander scours (49% and 29%, respectively). Beaver dams created an additional 14% of pool formations. Maximum pool depth (2.6 ft) and mean water depth (1.1 ft) provide adequate fish habitat. Forest Service Road 88 crosses Upper Willow Creek at the upstream boundary of this reach and has multiple culverts and pipes to drain excess floodwaters created by beavers. Otherwise, no evidence of physical channel alteration was noted. Bank and riparian vegetation conditions showed little evidence of grazing pressure, and utilization was likely due to browsing wildlife.

RWRP Polygon B

This polygon scored 91, the highest score of all polygons, and showed excellent vegetation and soil/hydrologic conditions. Grazing pressure was low, but some small areas were trampled by either livestock or wildlife. Channel conditions showed no evidence of lateral or vertical instability. Dense riparian vegetation throughout the polygon provided thermal protection and cover for fish. The polygon exhibited natural meanders, wide riparian zones and unaltered channels (Figure 14).

Figure 14 – Aerial photograph of a portion of R1-R4 Reach 2 and RWRP Polygon B



R1-R4 Inventory – Reach 3

Reach 3 extended 19,209 feet (stream mile 3.1 to 6.7, near Applegate Homestead Cabin) and included RWRP polygon C. This reach showed extremely good bank stability

(98%), woody composition (74%) and regeneration (75%). Pool/riffle ratios were very high, with 75% of the reach classified as pools. This high pool composition is due to intense beaver activity (Figure 15), with beaver dams accounting for 77% of the 120 pools. Submerged willow roots contributed to 18% of the pool formations. Maximum pool depths (2.6 ft) and mean water depths (0.8 ft) provide adequate fish holding areas. One bridge was constructed across the creek to provide access to logging operations on the valley's west side. No evidence of physical channel alteration was evident.

Figure 15 – One of several beaver dams throughout R1-R4 Reach 3

RWRP Polygon C

Polygon C showed good vegetation and soil/hydrologic scores and achieved a score of 86. Although this score was lower than polygons 1 and 2, the riparian polygon is still considered properly functioning. Evidence of light livestock use was recorded, and some banks showed trampling and bare soil. Utilization of preferred shrubs was noted but was not heavy enough to prevent regeneration. Banks showed evidence of light grazing pressure with occasional hoof shear and umbrella shrubs in the outer parts of the riparian zone.

R1-R4 Inventory – Reach 4

Reach 4 extended 15,037 feet (stream mile 6.7 to stream mile 9.5, bridge south of Luthje residence) and included RWRP polygon D. This reach showed good bank stability (90%), woody composition (66%) and regeneration (70%). As in reach 3, beaver dams created the majority of pool formations (49%). Submerged willow roots were also a large contributor to pool formations (33%). Maximum pool depth (2.6 ft) and mean water depths (0.9 ft) provide adequate fish rearing areas. Multiple ditches have been dug to divert flows away from the channel for flood irrigation. These ditches may cause fish to become trapped during low flows or when inactivated.

RWRP Polygon D

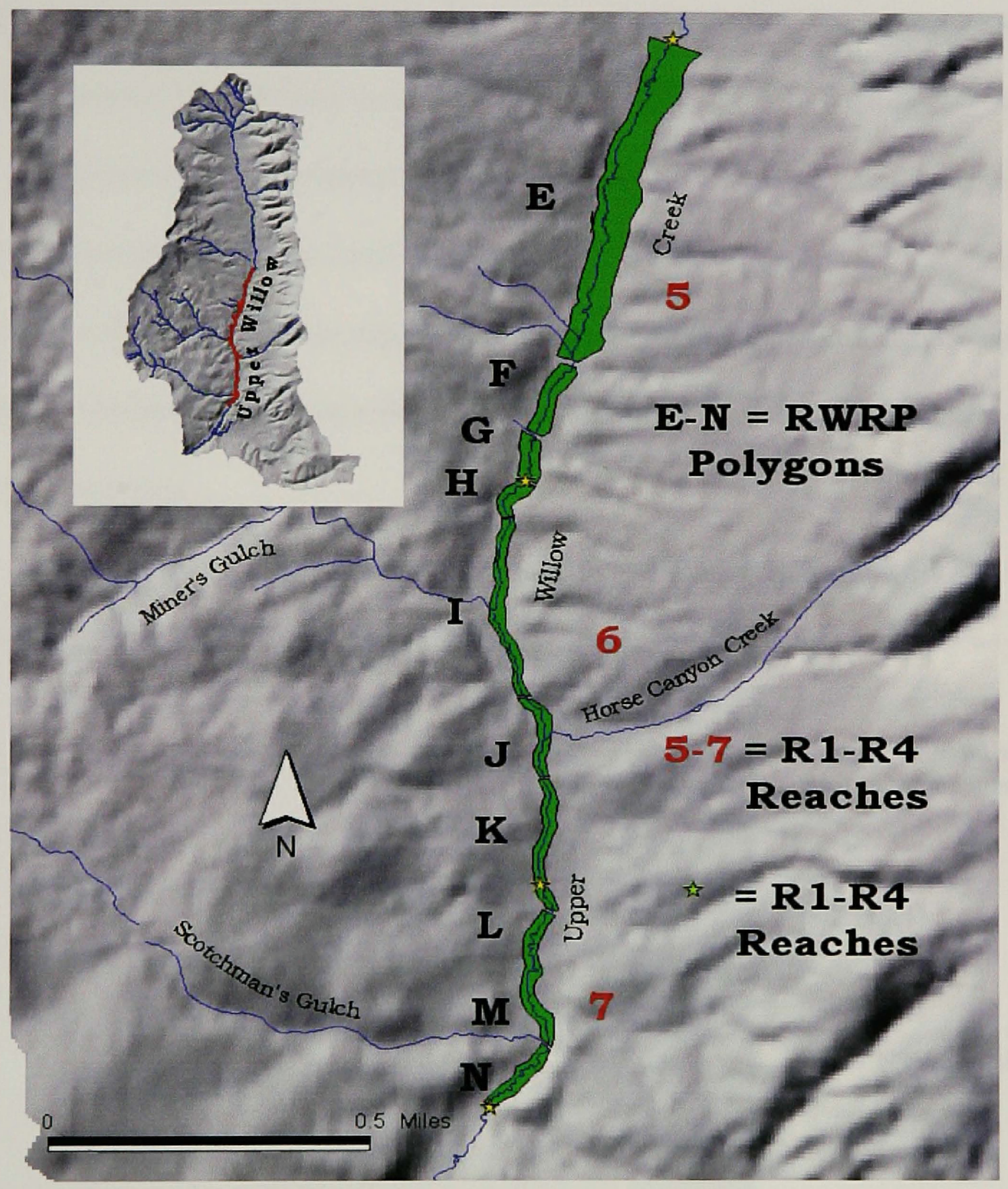
Polygon D achieved a score of 84 and was considered properly functioning condition. Moderate grazing pressure was evident in this reach. Hoof shear and bank trampling occurred on approximately 5% of the banks and browsing utilization was moderate. The riparian zone width was narrower than upstream reaches as pastures and hay fields are adjacent to the creek in approximately 40% of the reach. Invasive plant species including leafy spurge (*Euphorbia esula*) and common tansy (*Tanacetum vulgare*) were noted. The polygon also showed small percentages of disturbance-increaser species, including Kentucky bluegrass (*Poa pratensis*).

Overall, R1-R4 reaches 1-4 and RWRP polygons A-D were in good to excellent condition. Healthy riparian vegetation provided stable banks, added to pool complexity, and provided thermal cover and fish habitat. The channel showed virtually no signs of alteration, channelization or placement of artificial structures or fill. All riparian polygons were considered in properly functioning condition, and in-stream conditions provided excellent fish habitat.

Upper Willow Creek Section II

Section II included R1-R4 reaches 5-7 and RWRP polygons E-N (Figure 16).

Figure 16 - Upper Willow Creek Section II

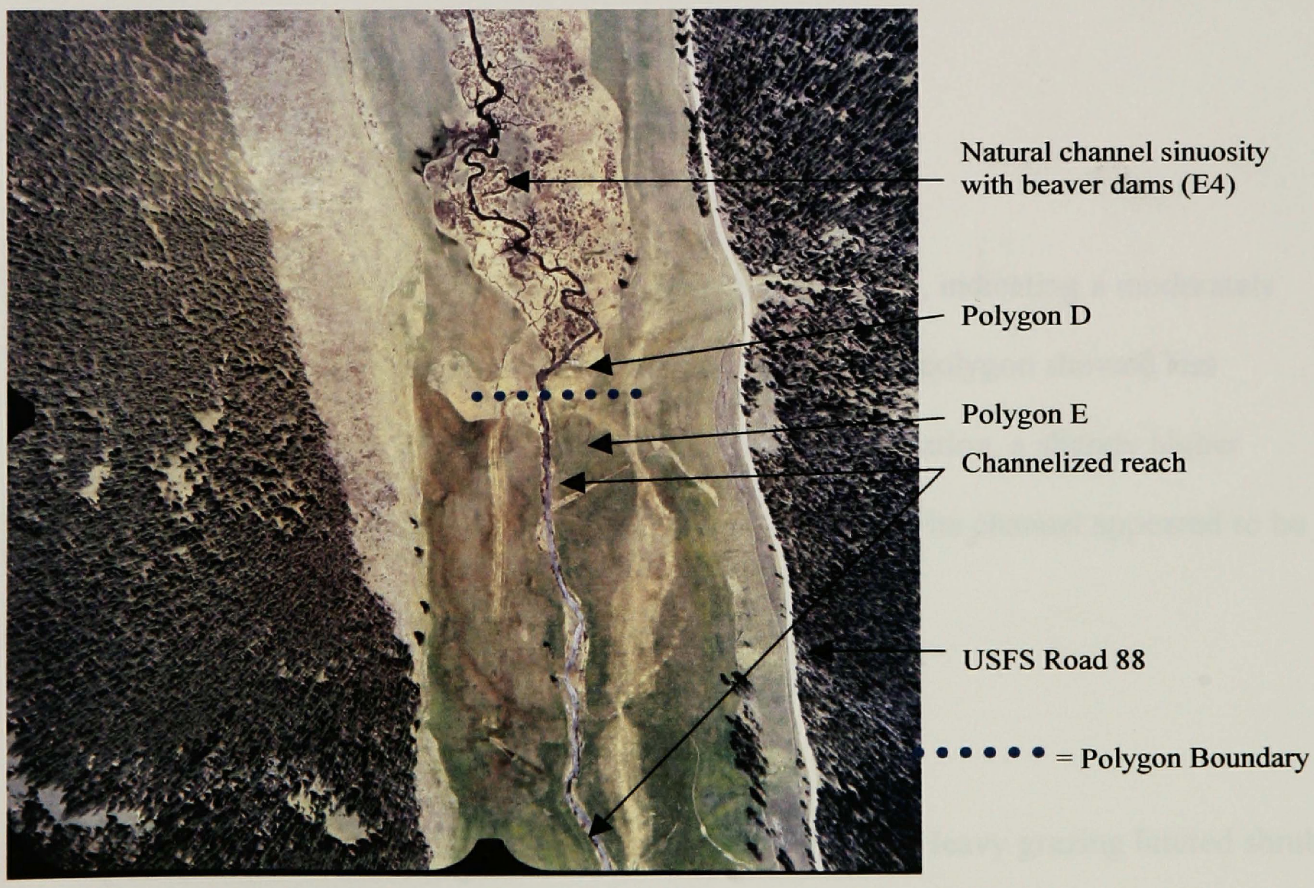


R1-R4 Inventory – Reach 5

Reach 5 extended 8,725 feet (stream mile 9.5 to stream mile 11.2, Miner's Gulch Bridge) and contained RWRP polygons E, F and G. Bank stability (75%), woody composition (28%) and regeneration (34%) were lower than upstream reaches. Approximately 50%

of the channel has been straightened within this reach (Figure 17). Due to channel modifications, riffle composition (45%) was higher than pool (37%). Long stretches of riffles and fast currents limited available fish habitat. Most pool formations resulted from woody root masses (40%), meander scours (33%) and boulders (24%). Maximum pool depth (2.3 ft) dropped slightly and mean water depth remained similar (0.8 ft) to reaches 2, 3 and 4. Large boulders and riprap stabilize two headgate diversion structures and a bridge, causing the channel to be confined. Riparian width was decreased approximately 25' on each side of channel due to adjacent meadows and hay fields along the entire reach. Multiple ditches divert water for irrigation throughout the reach, causing potential sources for trapped fish.

Figure 17 – Aerial photo of R1-R4 Reach 5 and RWRP polygons D and E



RWRP Polygon E

This polygon's low score (54) indicates a riparian area with severely reduced functional capability due to numerous vegetative and soil/hydrologic conditions. Several steeply angled banks were evident where channel incision occurred. This incised channel prevented livestock from easily accessing the stream. The channelized areas within this reach prevent access of the creek to a natural floodplain during high flows. The channel showed early stages of vertical instability and entrenchment due to high water velocities and absence of meander bends. Fortunately, the few remaining riparian shrubs showed light to moderate utilization and provided root mass for bank stability. Grazing pressure has resulted in higher coverage of herbaceous species more common in disturbed sites including Kentucky bluegrass and redtop (*Agrostis stolonfera*). Deep binding root mass was lacking, and decadent shrubs were common.

RWRP Polygon F

The polygon scored 74, and was considered functional-at-risk, indicating a moderately reduced functioning condition. Compared to polygon E, this polygon showed less grazing pressure, as evidenced by higher woody plant regeneration, a slightly higher percentage of deep binding root mass and less bare ground. The channel appeared to be meandering naturally, without extensively channelized areas.

RWRP Polygon G

The polygon scored 54, and was considered non-functional. Heavy grazing limited shrub regeneration and available root mass. Most riparian shrubs were decadent and species such as Kentucky bluegrass and Canada thistle (*Cirsium arvense*) found in disturbed areas inhabit much of the riparian area. The landowner installed riparian fencing in 2000 (Swanson 2001) and continuously monitors grazing within the riparian area, which may allow eventual recovery. Undercut banks provided good cover for fish, although many of these banks show signs of failure.

R1-R4 Reach 6

Reach 6 extended 13,979 feet (stream mile 11.2 to stream mile 13.9, north end of Bohrnsen property) and included RWRP polygons H, I, J and K. Polygon H (Figures 18 and 19), owned and managed by the BLM, may serve as a reference reach for a restoration project immediately downstream. Above and below this parcel, the creek flows through privately owned land.

Figure 18 – Aerial photo of RWRP Polygon H.

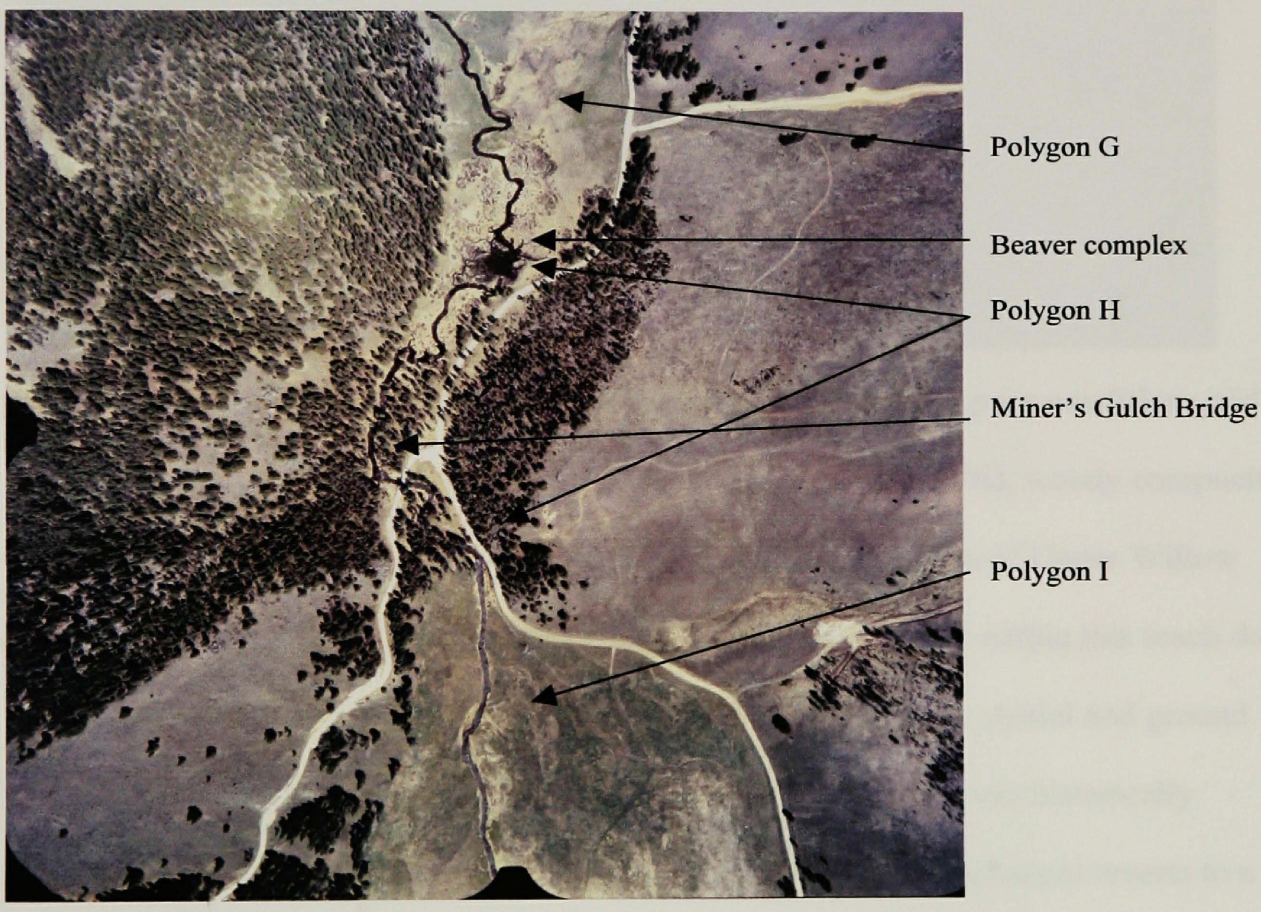


Figure 19 – Upper Willow Creek in RWRP Polygon H

Habitat parameters downstream of the BLM parcel showed very poor conditions and heavy channel and riparian alterations. Percent stable banks (53%), woody composition (12%) and regeneration (20%) were the lowest among all reaches of Upper Willow Creek. Mature, bank-stabilizing shrubs were almost nonexistent within this reach due to extensive willow eradication by herbicide and physical removal. Aerial and ground photographs (Figures 20 and 21) show the majority of the reach was historically channelized, although numerous meanders currently exist as the channel reverts to a natural, more stable sinuosity. Severe lateral scour associated with the reestablishing meander bends resulted in a higher pool composition (53%) than reach 5, which was also severely channelized. Severe scouring created several meander pools, higher pool/riffle ratios in reach 6 and slow-water habitat for fish.

Figure 20 – Aerial Photo of a Portion of Upper Willow Creek R1-R4 Reach 6

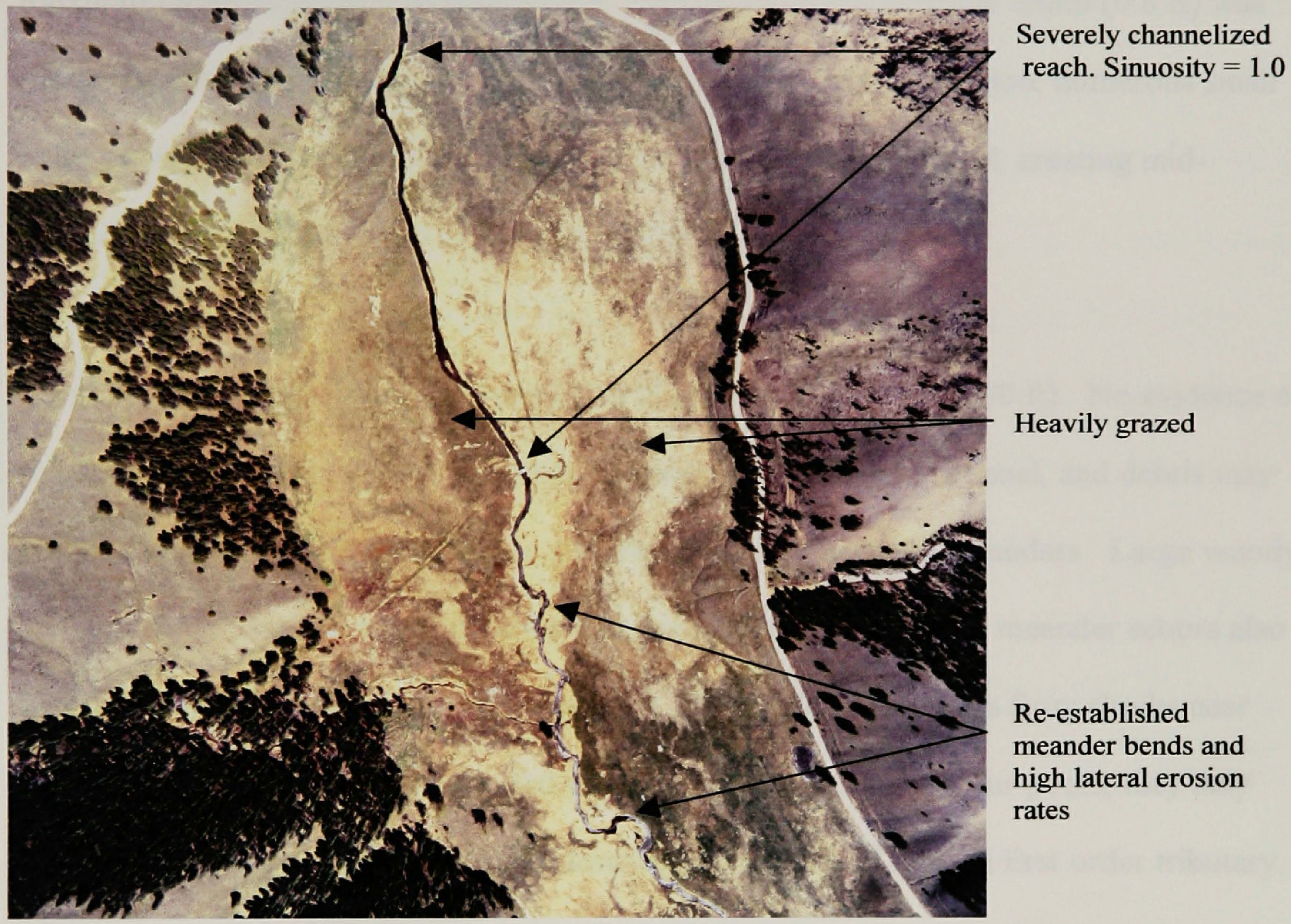


Figure 21 – Channelized Reach in Upper Willow Creek R1-R4 Reach 6

Maximum pool depth (2.2 ft) was slightly shallower and mean water depth (0.8 ft) was similar to upstream reaches. Although mature shrubs were uncommon, numerous small willows and alders were beginning to take hold at the baseflow level, creating mid-channel scour pools within straightened reaches.

Large woody debris was fairly common in this reach (8.2 items/1,000 ft). No evidence of mature cottonwoods or other tree species were visible near the channel, and debris may have been placed along the banks as a barrier to aid in confining meanders. Large woody debris and submerged root masses formed most pools (46%), while meander scours also contributed highly to pool formations (43%). Although root masses from shrubs near baseflow channel elevations provided structure for mid-channel scour pools, they may also have been contributing to active downcutting. Miners Gulch, a first order tributary, enters Upper Willow Creek approximately 0.4 miles downstream from the upper boundary of the reach. This tributary, which may have been historically altered, showed evidence of headcutting near the confluence.

Three bridges provided stream crossings within reach 6 and are reinforced with heavy riprap. One of these bridges had an inadequate span, as evidenced by a mid-channel gravel bar immediately upstream. During high flows, the bridge's dimensions likely act as a dam, creating an artificial pool upstream and allowing significant channel widening as substrates deposit. Lateral erosion was evident both upstream and downstream of this bridge.

Three log drop-structures are also present within reach 6. These may have been installed by the former landowner as gradient control or diversion structures. Single logs span the entire channel and are reinforced with rock to prevent scouring. Although these logs create both plunge pools and slower slackwater immediately above, their presence acts as a check-dam. Sediments accumulating upstream of these structures will eventually create a shallower, wider channel. Once these conditions exist, high flows may significantly erode the banks around the structures, causing heavy sedimentation and ultimate failure of structure.

The downstream boundary of reach 6 was defined by a large irrigation diversion structure. This structure was classified as a partial fish passage barrier during both high and low flows. Water passes through narrow slots between wooden flashboards approximately 4 feet high during the irrigation season. High water velocities and no jump pool may create difficult conditions for both adult and juvenile fish movement upstream of this barrier.

RWRP Polygons I, J, and K

Aerial photos show the former landowner built fencelines for separately managed pastures. The current landowner maintains these areas as a single-managed property, therefore they will be addressed together. These polygons achieved scores of 51, 41 and 40 and were considered non-functional. Riparian vegetation conditions of the entire reach were extremely poor, resulting in high coverage of undesirable species, decadent material and bare ground. Continued grazing has resulted in heavy use of shrubs and poor vegetative cover of stream banks and several showed unstable characteristics (Figure 22). Lack of overhanging vegetation allowed no thermal protection. Extensive hoof shear, trampling and pugging/hummocking further deteriorated bank conditions (Figure 23). Lateral erosion was evident on virtually every meander bend due to barren banks and lack of binding root mass.

Figure 22 – Severe lateral erosion

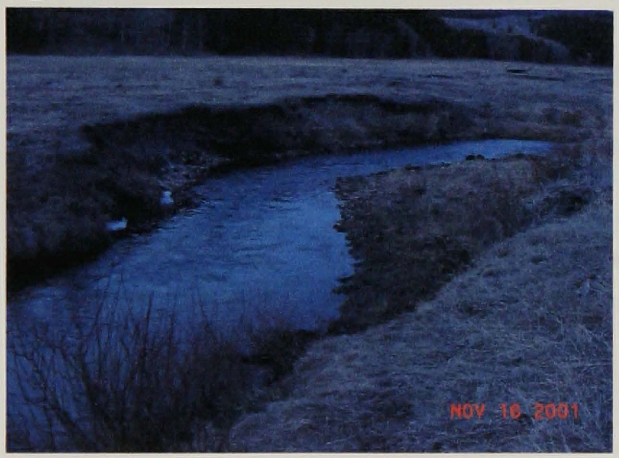


Figure 23 – Hoof shear

Long channelized reaches prevent flows from accessing a natural floodplain, and the channel showed characteristics of downcutting. Human-caused bare ground was very high and channel alterations add to the overall very poor riparian conditions.

R1-R4 Inventory – Reach 7

Reach 7 extended 7,524 feet (stream mile 13.9 to stream mile 15.7, lower property boundary south of Scotchman's Gulch Bridge) and included RWRP Polygons L, M and N. Habitat parameters showed poor channel and riparian conditions with many alterations. Percent stable banks (74%), woody composition (15%) and regeneration (29%) remained very low overall, but showed slightly improved conditions from reach 6. As in reach 6, most of this reach was channelized. The channel is attempting to return to a natural sinuous pattern and due to low woody vegetation composition on the banks, heavy lateral erosion was occurring on virtually all meander bends. Riprap existed on numerous banks to stabilize heavily eroding areas. Hoof shear and trampling were evident in numerous reaches. Pool composition (53%) increased from reaches 5 and 6, revealing more diverse habitat complexity and a less riffle dominated reach. Most pool formations were due to meander scours and submerged roots (46% each). Boulders and beavers added to pool formations, although most beaver dams were physically removed to prevent flooding of hayfields. Maximum pool depth (2.3 ft) and mean water depth (0.8 ft) were similar to upstream reaches, providing adequate holding water for fish. Artificially built banks throughout channelized areas prevent high flows from accessing a floodplain, resulting in a very narrow riparian zone within most of the reach.

RWRP Polygon L

The polygon was given a score of 46 and considered non-functional. This polygon revealed heavy livestock use in the area directly adjacent to the Bohrnsen residence. This area is likely a winter pasture for cattle. Riparian vegetation within this area was very sparse and heavy lateral erosion was evident. This area could be a significant source of both sediments and nutrients, as riparian buffers were not adequate to prevent overland runoff directly into the creek. Bare ground was evident throughout the polygon, resulting from livestock access.

RWRP Polygon M

This polygon included the main Bohrnsen property from the winter pasture to Scotchman's Gulch Bridge. This polygon was considered non-functional and achieved a score of 53. Due to channelization, artificially built banks and hayfield/pasture building, the riparian zone within this polygon was very narrow. Several headgates and small bridges have been installed and riprapped for protection. Herbaceous vegetation included disturbance-increaser species including Kentucky bluegrass (*Poa pratensis*) and smooth brome (*Bromus inermis*). Heavy grazing has resulted in poor shrub density, low available root mass and hoof shearing.

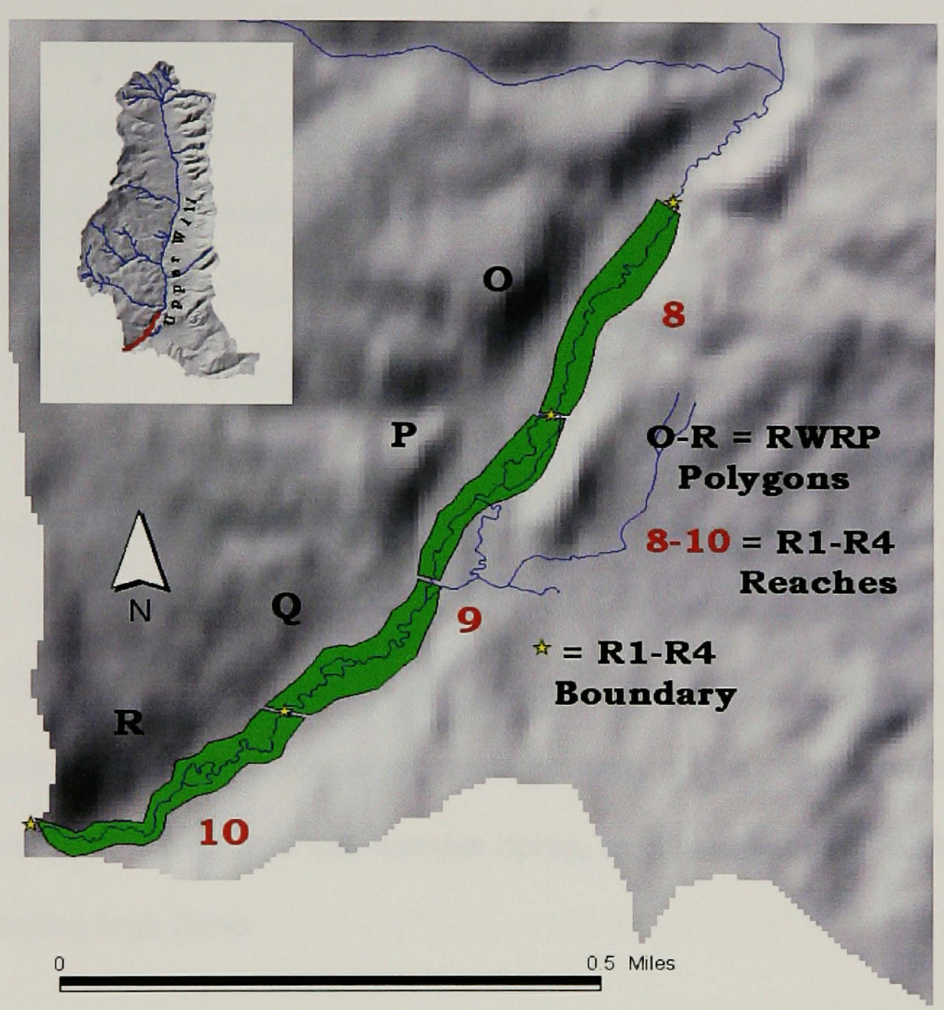
RWRP Polygon N

This polygon covered the upper 1/3 of a subdivided section called Willow Rock Ranchettes. The polygon scored 51 and was considered non-functional. High utilization of riparian shrubs suggested heavy grazing as evidenced by virtually all willows having an umbrella shape and herbaceous vegetation appearing very sparse. Intense grazing prevented regeneration and adequate deep binding root mass. Banks showed multiple areas of pugging, trampling and hoof shear. Spotted knapweed was evident at Scotchman's Gulch Bridge as a result of disturbance and vehicle use. The channel appeared to be naturally meandering and vertically stable, however poor stabilizing root mass allows lateral erosion throughout multiple meander bends.

Upper Willow Creek Section III

Section III included R1-R4 Reaches 8-10 and RWRP Polygons O-R (Figure 24).

Figure 24 - Upper Willow Creek Section III



R1-R4 Reach 8

Reach 8 extended 10,240 feet (stream mile 15.7 to stream mile 17.2, south end of Willow Rock Ranchettes section). Bank stability (71%), woody composition (30%), and regeneration (23%) remained fairly low. Few alterations were evident throughout the entire reach, and the channel appeared to have a natural meander pattern. Pool composition was higher (68%) as a result of natural channel patterns. Woody debris and meander scours provided most pool formations (47% and 46%, respectively). The presence of large woody debris was higher in this reach (9.0 items/1000 ft) than any other reach. A few mature cottonwoods were scattered throughout the reach, but were not necessarily associated with the active channel or riparian areas. Beaver activity was evident, with two dams remained intact. Pool depths (2.1 ft) and mean water depths (0.6 ft) were slightly shallower than upstream reaches. Riffle composition (18%) decreased from the four previous upstream reaches.

One short reach (approximately 200 ft) of the channel appeared channelized near a newly built house. This area included riprap and a diversion structure for a ditch flowing adjacent to the Upper Willow Creek Road. One bridge was constructed across the channel to provide landowner access to private property on the valley's west side. This bridge was reinforced with rock and wooden riprap, but did not appear to alter channel conditions during high flows.

RWRP Polygon O

This polygon covered the lower 2/3 of the Willow Rock Ranchettes, managed by multiple landowners. Riparian conditions appeared better within polygon O than polygon N, and was considered properly functioning (score = 82). Evidence of light grazing existed, with some bank trampling, pugging and bare ground. The channel was mostly stable laterally with high percent root mass. Riparian vegetation showed light utilization and some decadent shrubs were evident, especially in the downstream end of the polygon.

R1-R4 Reach 9

Reach 9 extended 11,798 (stream mile 17.2 to stream mile 19.5, boundary between Brewton and Gilles property) and included RWRP Polygons P and Q. Bank stability (86%) was much higher than the five previous reaches. Although woody composition (37%) and regeneration (34%) increased from the four previous reaches, it remained low. Some channelized areas exist within the reach; however, the riparian vegetation appeared to stabilize most banks. The reach showed natural sinuosity patterns, resulting in high pool composition (63%). Most pools were formed by wood (52%) and meander scours (44%). Boulders and beavers also contributed to pool complexity. Pool depths (2.6 ft) and mean water depths (1.0 ft) were deeper than the previous four upstream reaches, providing adequate slow-water areas for fish.

RWRP Polygon P

This polygon scored 60 and was considered non-functional. Channelized areas were evident, although riparian vegetation has recovered and stabilized lateral erosion along most banks. Some evidence of early downcutting was evident near irrigation diversions. Hay production in adjacent meadows allowed minimal width of riparian zones. Disturbance-increaser species were common, including Kentucky bluegrass, redtop and Baltic rush (*Juncus balticus*). Invasive leafy spurge (*Euphorbia esula*) and common tansy (*Tanacetum vulgare*) were also evident along the stream banks. Woody vegetation appeared heavily utilized and were mostly umbrella shaped. The reach contained at least four diversion structures to provide irrigation flow.

RWRP Polygon Q

This polygon scored 74 and was considered functional-at-risk. Higher percentages of available root mass and vegetative cover provided higher vegetative scores than polygon P. The reach lacked channelized areas and showed no signs of active downcutting. Disturbance-increaser vegetation remained evident, and some bare ground existed along the channel, especially near headgates and diversions.

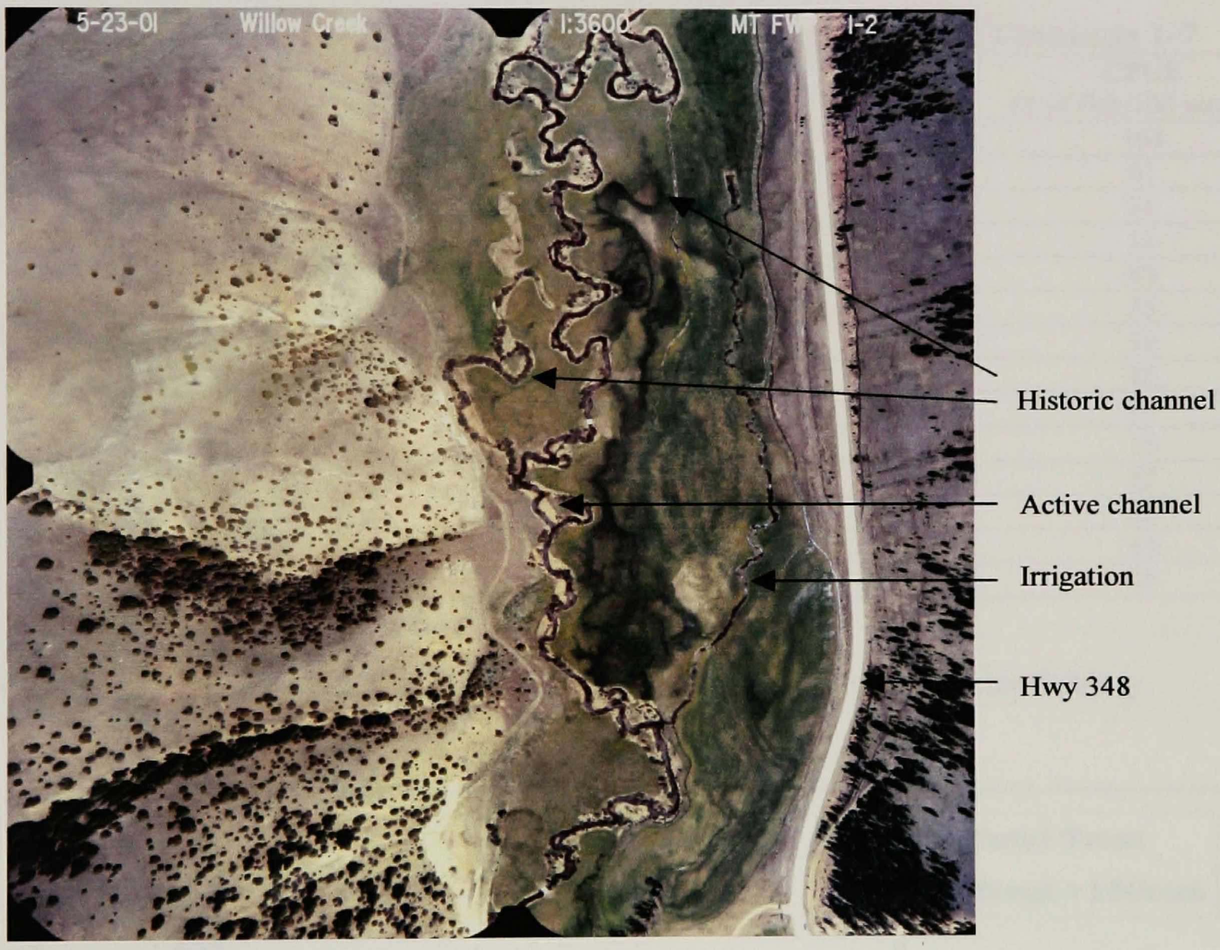
R1-R4 Reach 10

Reach 10 extended 9,627 feet (stream mile 19.5 to stream mile 21.3, bridge just upstream from confluence with Rock Creek) and included RWRP Polygon R. Bank stability (71%) was fair, yet banks associated with numerous meander scours were failing due to poor woody composition (36%). Regeneration improved in this reach (69%) and was the highest in sections II and III. Pool composition was high (63%) and riffle composition remained low (14%) due to a natural sinuosity (1.9) channel pattern. Submerged woody roots and meander scours provided the primary pool formation (61% and 38%, respectively). Pool depths (2.4 ft) and mean water depths (0.8 ft) were adequate for fish.

RWRP polygon R

This polygon scored 70 and was considered functional-at-risk. Inactive, historic channels were evident across the floodplain and the channel appeared to show natural sinuosity patterns and no channelization (Figure 25). Lack of woody root mass provided some lateral erosion on meander bends. Livestock grazing was evident due to numerous umbrella shrubs, yet hoof shear and trampling were sparse due to high percentages of steep banks and difficult access to the creek. Disturbance increaser species were common throughout the channel, and dense knapweed was present along the downstream end of the polygon near an access road.

Figure 25 – Aerial photo of Upper Willow Creek in R1-R4 reach 10 showing natural sinuosity (E4), historical channels, and narrow riparian zone just upstream of the confluence of Rock Creek



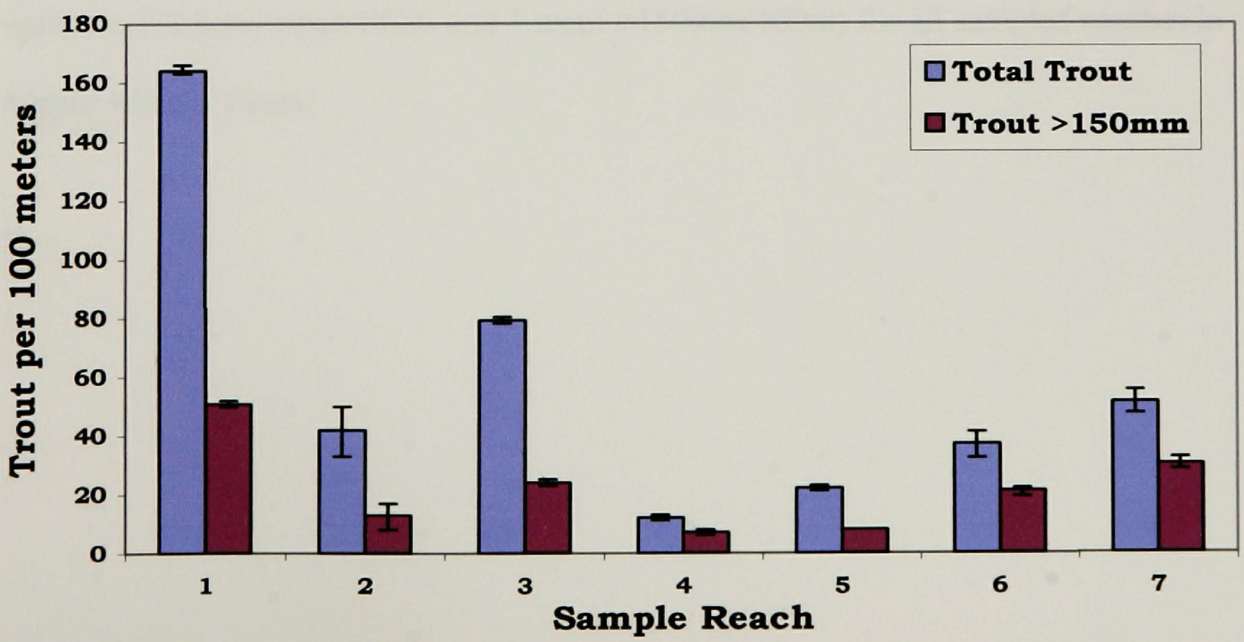
Fish Population Estimates

Population estimates and catch-per-unit-effort (CPUE) were recorded at each electrofishing transect on Upper Willow Creek (Table 3 and Figure 26). CPUE estimates fish densities by a standard transect length (100m) but are not an accurate depiction of population estimates.

Table 3 – Population Estimates and CPUE for Electroshocking Transects 1-7

Transect #	R1-R4 Reach	Length (meters)	Population Estimate	Standard Error	CPUE (# of fish/100 meters)
1	3	143	164 total trout	1.88	164
			73 trout >150mm	0.67	61
2	5	166	71 total trout	7.16	36
			22 trout >150mm	4.08	11
3	6	98	78 total trout	0.51	80
			24 trout >150mm	0.11	25
4	6	179	74 total trout	2.55	39
			42 trout >150mm	3.23	22
5	6	101	40 total trout	0.39	41
			16 trout >150mm	0.00	16
6	8	474	179 total trout	10.30	32
			103 trout >150mm	4.08	20
7	9	105	55 total trout	1.96	44
			32 trout >150mm	0.79	31

Figure 26 – Population Estimates for Upper Willow Creek Electrofishing Reaches 1-7



Electrofishing reach 1, located in R1-R4 reach 3 showed the highest population estimate of 164 trout/100m and 51 trout >150mm/100m. Fish in this transect were primarily westslope cutthroat, eastern brook trout and whitefish. Small numbers of brown trout, hybrids, long nosed suckers and sculpins were also present.

Sample reach 3, located in the BLM-managed area at Miner's Gulch Bridge, showed the second highest population estimate of 79 trout/100m and 24 trout >150mm/100m. This sample reach was in a short, but healthy length of creek between two reaches of severely channelized areas (reach 5 and reach 6). Sample reach 3 contained primarily westslope cutthroat and whitefish, but also included one adult bull trout (262 mm). Small numbers of brown trout, rainbow trout and cutthroat/rainbow hybrids were also present. Sample reaches 2 and 4-7 showed lower population estimates of 12-51 trout per 100m and 7-30 trout >150mm per 100m. The primary species were westslope cutthroat trout and whitefish. A total of 11 bull trout were sampled in sample reach 2 and 6 (n=2 and 9, respectively). Sample reach 4 within R1-R4 reach 6 showed the lowest population estimate (12 total trout/100m and 7 trout >150mm/100m) for all sampled reaches in Upper Willow Creek.

Channel Morphology

The morphological characteristics measured in Upper Willow Creek included width/depth ratios (Figure 27), channel substrate (Figures 28 and 29) and sinuosity. Results of these measurements were used to attempt assigning Rosgen channel classification for each reach (Table 4). Accurate Rosgen classification criteria include entrenchment ratio and channel slope, which were not determined in this study.

Figure 27 – Width/Depth Ratios at Upper Willow Creek Sites A-J

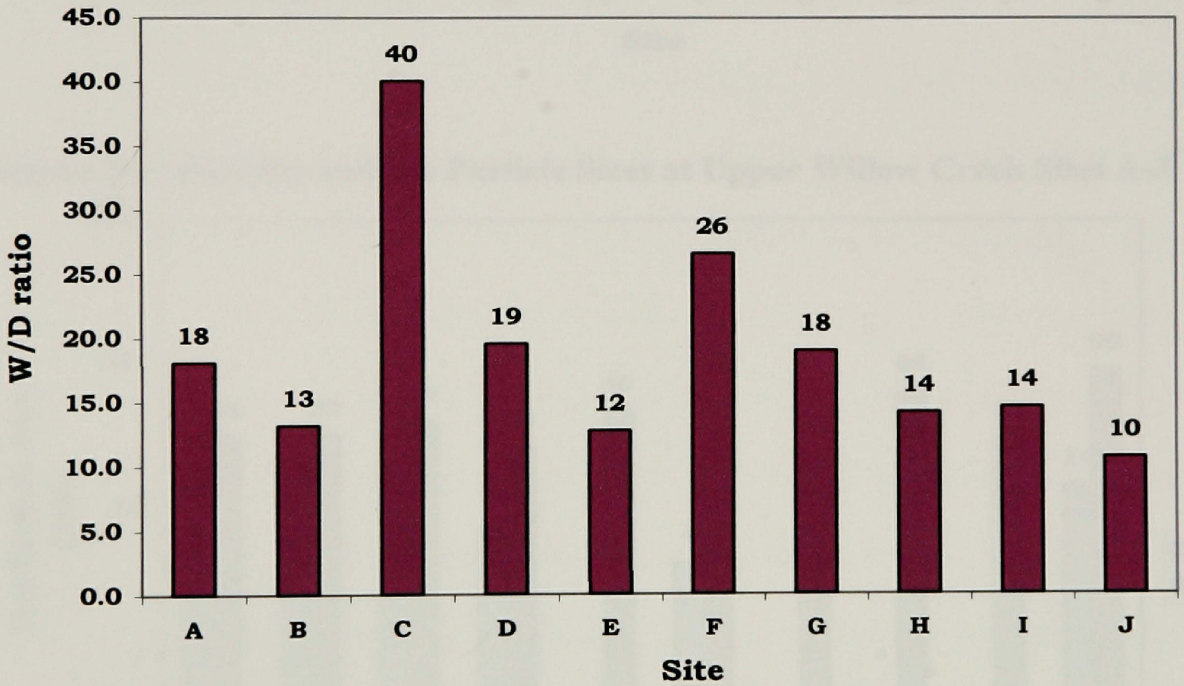


Figure 28 – Riffle D50 and D84 Particle Sizes at Upper Willow Creek Sites A-J

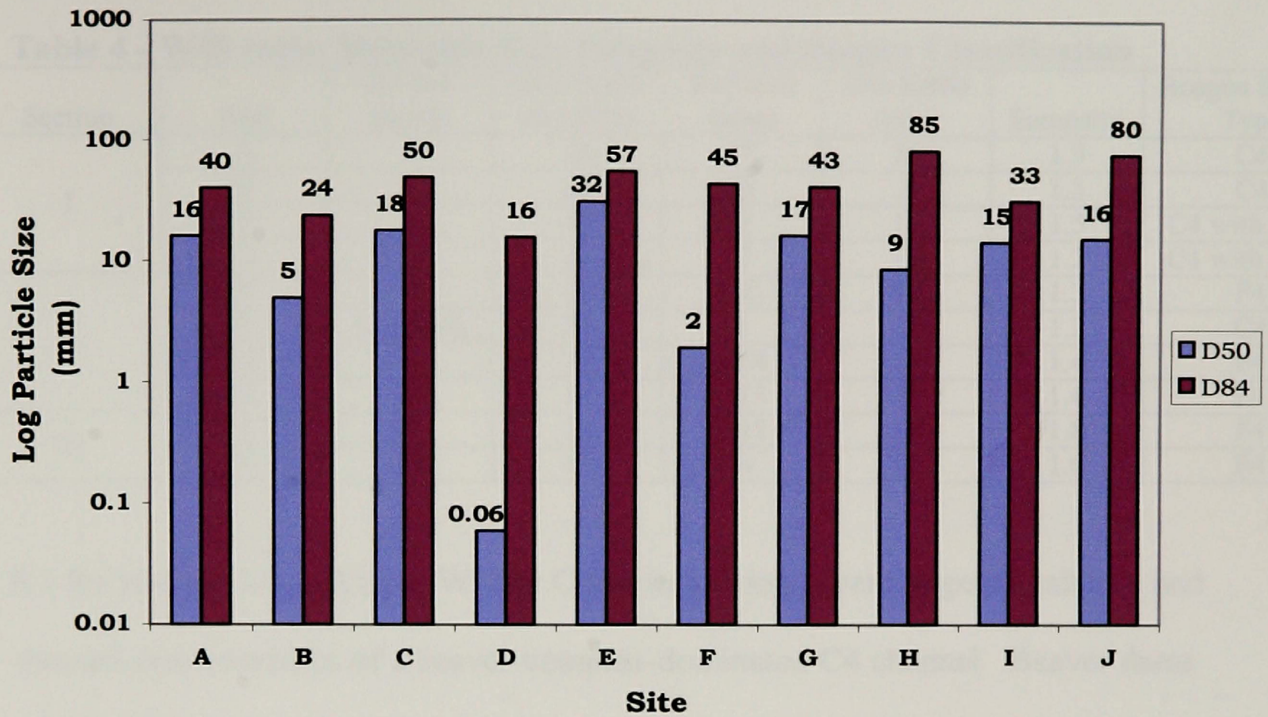


Figure 29 – Pool D50 and D84 Particle Sizes at Upper Willow Creek Sites A-J

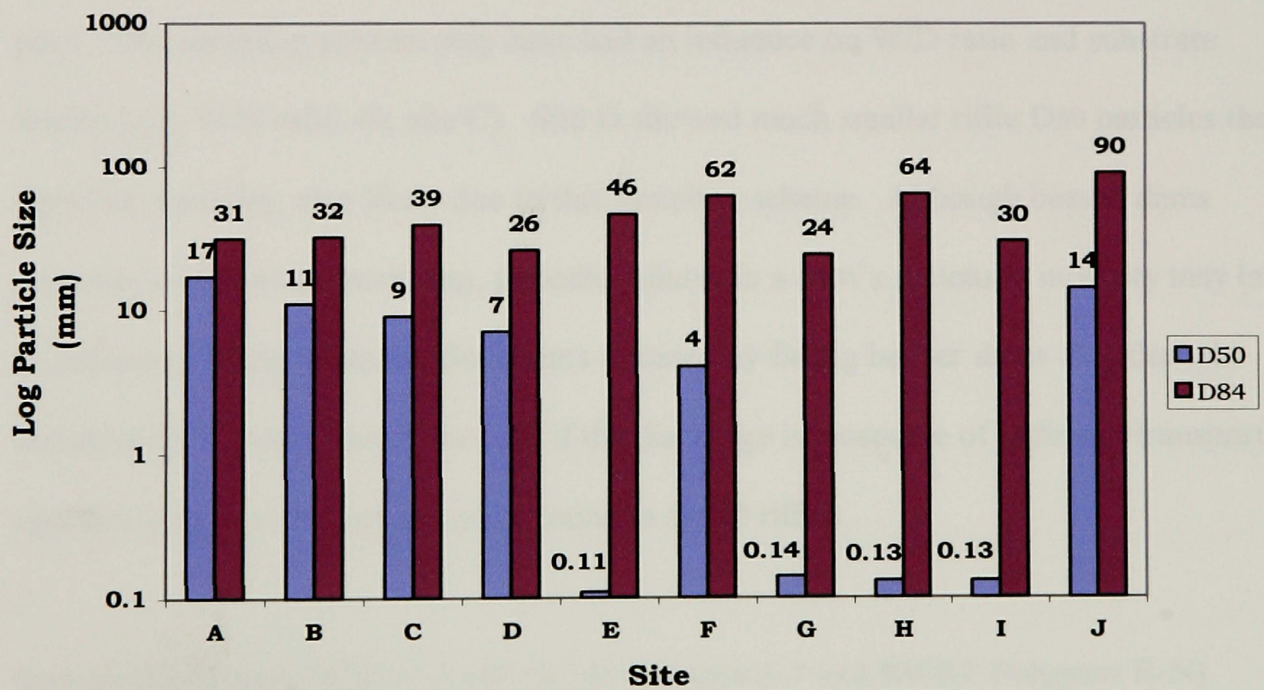


Table 4 - W/D ratio, Substrate Size, Sinuosity and Rosgen Classification

Section	Site	R1-R4 Reach	W/D Ratio (at riffle)	D_{50} Pool (mm)	D_{50} Riffle (mm)	Sinuosity	Rosgen Stream Type
I	A	1	18	17	16	1.3	C4
	B	2	13	11	5	1.3	C4
	C	3	40	9	18	1.5	C4 with dams
	D	4	20	7	.06	1.2	C4 with dams
II	E	5	13	0.11	32	1.3	F4
	F	6 (BLM)	26	4	2	1.2	C4
	G	6	19	0.14	17	1.4	F4
	H	7	14	0.13	9	1.4	F4
III	I	8	15	0.13	15	1.8	F4
	J	10	11	14	16	1.6	E4

R1-R4 reaches 1-4 of Upper Willow Creek in Section I were largely unaltered and showed characteristics of a beaver-complex-dominated C4 channel. Beaver dams throughout reaches 3 and 4 created difficult sampling conditions due to few adjacent pool/riffle locations. Riffles were sampled immediately below dams upstream of the next pool. This sampling scheme may have had an influence on W/D ratio and substrate results (e.g. W/D ratio 40, site C). Site D showed much smaller riffle D_{50} particles than pool D_{50} particles, also likely due to this sampling scheme. Although beaver dams generally create a sediment trap, periodic failures in a dam's structural integrity may lead to sediments being released. Sediments released by failing beaver dams may deposit immediately downstream of the dam if the discharge is incapable of sediment transport, explaining the smaller particle sizes found in site D riffles.

Section II of Upper Willow Creek (R1-R4 reaches 5-7 and RWRP Polygons E-N) included several channelized sections, altered riparian vegetation and relocation of the original channel. Reach 5 showed an overall sinuosity of 1.3, although this included several channelized areas. The historical, unaltered stream likely had a higher sinuosity between 1.5 and 2.0 given substrate and valley characteristics. The low sinuosity and W/D ratio (13) suggest a downcuting channel as a result of added energy placed on the bed throughout channelized areas. Average substrate size in pools within this reach dropped to 0.11mm indicating sediment deposition. Although historical, natural conditions would have likely produced either a C4 or E4 channel, current conditions showed characteristics of an incised Rosgen F4 channel.

Site F was sampled within the BLM-owned parcel at Miner's Bridge. The valley constricted at this point (Figure 18) creating a slightly steeper gradient. Although W/D ratio increased to 26, sinuosity remained low (1.2) and substrate remained gravel-dominated, indicating a C4 channel.

Sample site G was sampled within the proposed restoration project reach 6. As in reach 5, channelization has altered the natural channel dimensions, making Rosgen classification difficult to pinpoint. Sinuosity (1.3), W/D ratio (19) and substrate composition (pool D_{50} = 0.14mm, D_{84} = 24mm) indicate the channel has been altered from either a C4 or E4 to an F4 channel type. Headcutting was apparent at confluencing tributaries, and artificially built dirt banks create an entrenched channel. The channel is re-establishing a natural meander pattern by lateral and vertical erosion, as evidenced by short reaches of higher sinuosity (Figure 20). The pool sampled within this reach showed a very low D_{50} (0.14mm) indicating fine substrate deposition. Results suggest the channel is scouring both vertically and laterally while depositing sediments in slower velocity pools both within and downstream of this reach. This process of erosion and deposition will likely continue throughout this reach until the channel slope decreases to a gradient capable of maintaining a stable channel pattern subject to normal flow conditions.

Sample site H within reach 7 showed similar conditions to sample site G in reach 6. The sinuosity (1.3) and W/D ratio (14) again showed a confined channel attempting to re-establish a natural pattern. Pool substrate showed continued sediment deposition, as D_{50} particles were 0.13mm. The current channel shows characteristics of an incised F4 channel, although natural conditions likely produced a C4/E4 pattern.

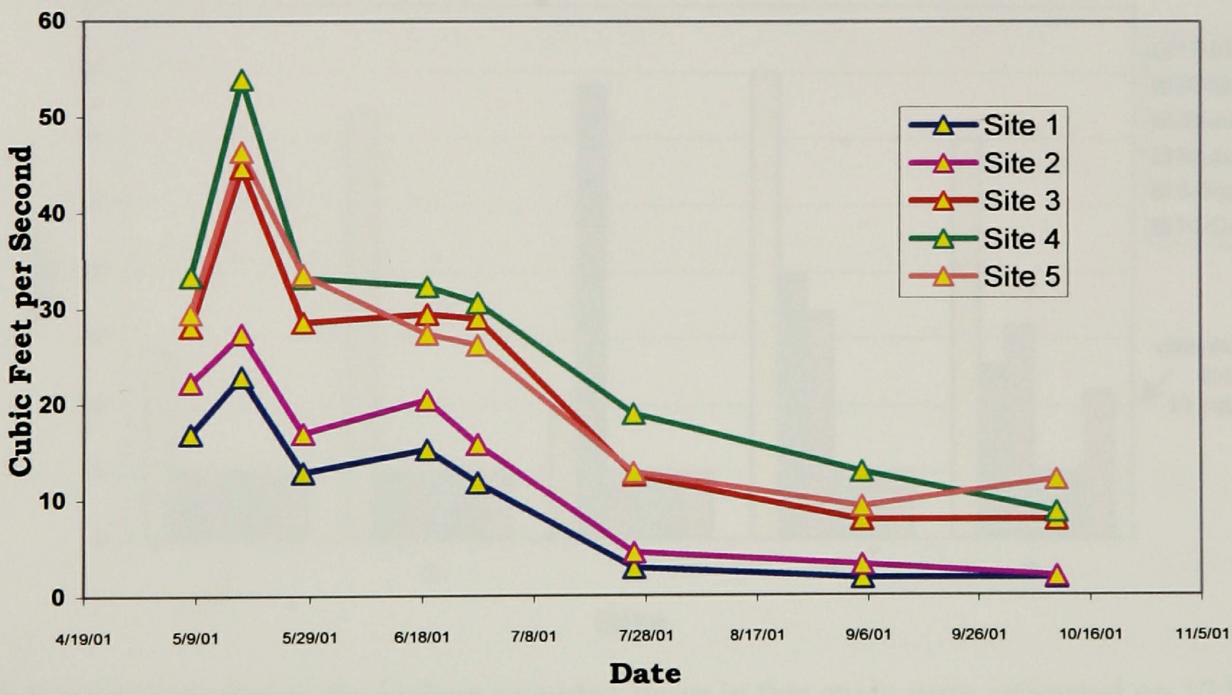
Sample site I within reach 8 showed a higher sinuosity pattern (1.8) than reaches 5, 6 and 7 due to the absence of channel alterations. The W/D ratio remained fairly low (15), indicating the channel may be in early stages of downcutting. Pool substrates continued to show fine sediment deposition, as D_{50} particles remained very low (.13mm). The channel showed characteristics of a Rosgen F4 stream.

Sample site J within reach 10 showed unaltered conditions relative to all mid and lower reaches of Upper Willow Creek. Historically active channels existed across the floodplain (Figure 25). Sinuosity (1.6), W/D ratio (11) and gravel substrates indicated a Rosgen E4 channel. The channel did not show evidence of downcutting and pool particle sizes increased, indicating a decrease in fine sediment deposition (pool D_{50} = 14mm) (Figure 29).

Nutrients and Sediments in the Water Column

Upper Willow Creek discharge was measured at sample sites 1-5 to permit rough estimation of sediment and nutrient loads. Discharge was recorded once or twice per month between 17 May and 10 October 2001 (Figure 30). Discharge peaked on 17 May and reached baseflow levels by 26 July. Discharge increased downstream between sites 1 through 4. Site 5 recorded lower discharge than site 4 except on 17 May and 10 Oct. Although some flows are lost to irrigation in this reach, loss to groundwater is also probable as this area of the basin is considered alluvial class geologic material (Carnefix 2002, Jensen 1998).

Figure 30 – Discharge of Upper Willow Creek in 2001 at Sites 1-5

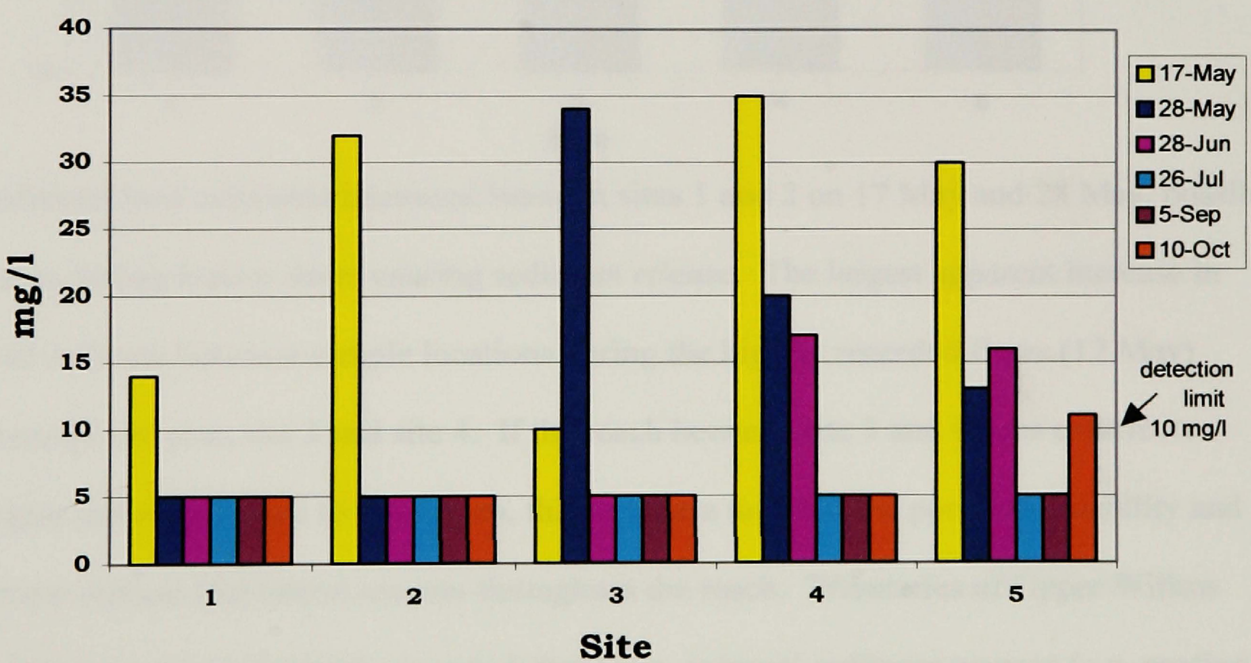


Total Suspended Sediments

Total suspended sediment (TSS) concentrations for sites 1-5 in Upper Willow Creek appeared to peak on 17 May, during the highest flows recorded for the study (Figure 31).

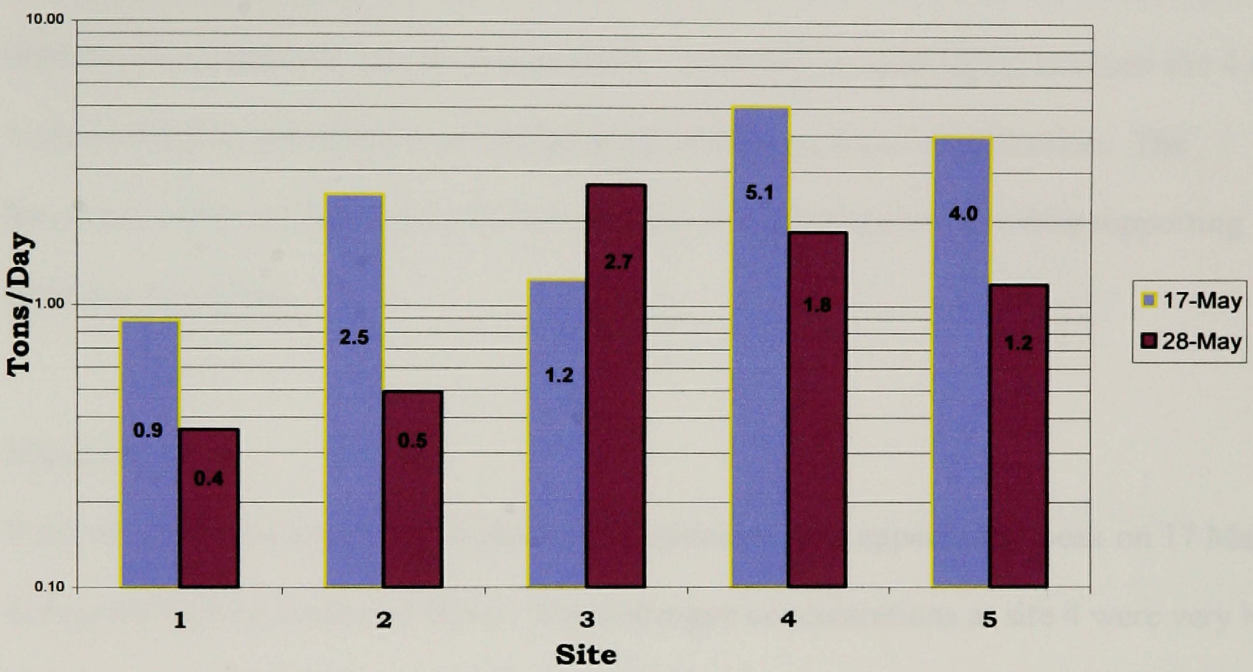
Sediment concentrations on 17 May ranged from 10 mg/l at site 3 to 35 mg/l at site 4. Site 3 may have produced lower sediment concentrations due to a beaver dam approximately 200 meters upstream of the sample site, providing a sediment trap. This dam was periodically breached by landowners to prevent excessive flooding during high flows. The spike in TSS concentration on 28 May between site 2 and site 3 may have been due to the dam being breached and releasing accumulated sediments. Sediment concentrations decreased at all sample sites after the peak flow. Samples were below the detection limit (10 mg/l) at all samples after the 28 June sample date except on 10 October (all results on figure 24 shown at 5 mg/l were below detection).

Figure 31 – Total Suspended Sediment Concentration at Upper Willow Creek Sites 1-5



Sediment loads during the highest recorded flows in this study were estimated on 17 May and 28 May by multiplying sediment concentration by discharge during that sample day (Figure 32). Sediment concentrations at sites 1 and 2 on May 28 were below detection (10 mg/l), therefore a concentration of 5 mg/l was used to estimate sediment loads for those dates. Because this is not the standard method of estimating sediment loads, the following discussion of loads is highly speculative.

Figure 32 – Sediment Load Estimates During 2001 Peak Flows at Upper Willow Creek Sample Sites 1-5

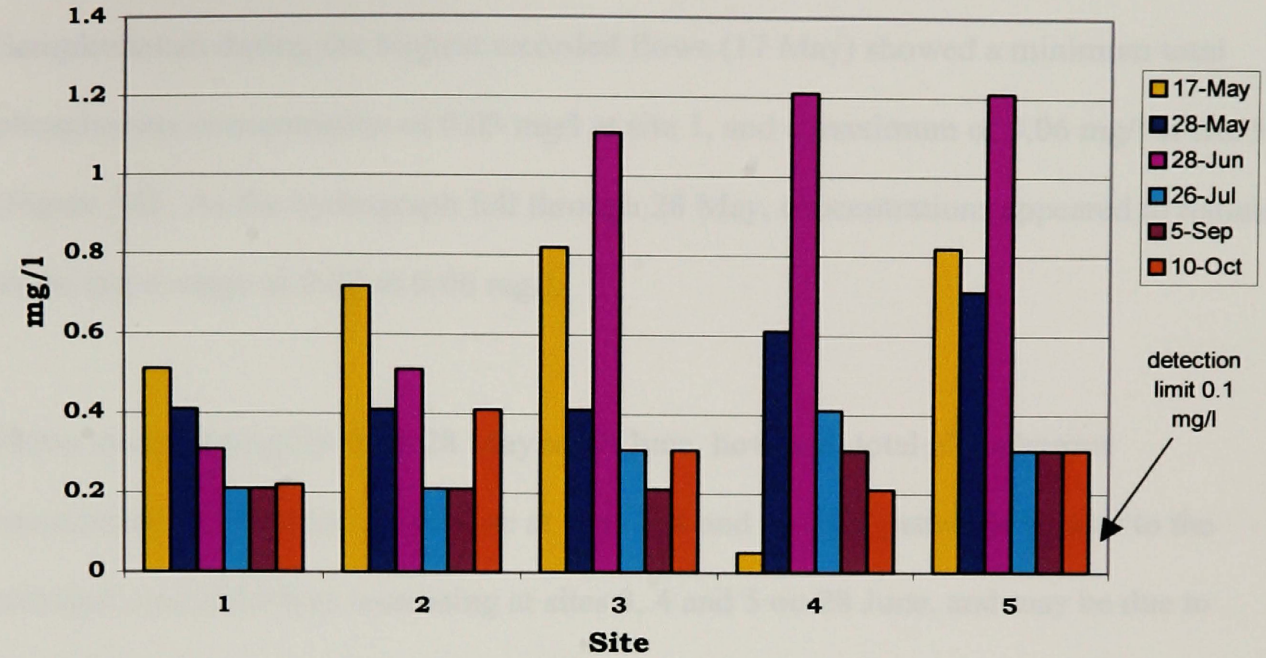


Sediment load estimates increased between sites 1 and 2 on 17 May and 28 May, possibly due to failing beaver dams causing sediment release. The largest apparent increase in load estimate between sample locations during the highest recorded flows (17 May) occurred between site 3 and site 4. If the reach between site 3 and 4 does contribute higher sediment inputs to the stream, this may be a result of the poor bank stability and severe vertical and lateral erosion throughout the reach. Tributaries of Upper Willow Creek were not individually sampled; therefore, external sediment sources (e.g. erosion from logged areas and roads) cannot be quantified. Discharge decreased between 54% and 71% between 17 May and 28 May, but sediment load estimates remained high at site 3, 4 and 5. Although TSS concentrations were below detection at sites 1 and 2 on 28 May, sediment loads were estimated for these sites to compare sediment loads between sites. These results suggest the reach between site 2 and site 3 contributed the highest sediment inputs to the stream on 28 May. This appears in agreement with the R1-R4 survey, which indicated that the reaches between sites 2 and 3 and between 3 and 4 had the poorest bank stability in Upper Willow Creek. Estimated sediment load decreased between site 4 and site 5 on all sample dates. Substrate samples taken between site 4 and 5 showed higher percentages of fine particles, indicating areas of deposition. The decreased sediment load estimates between site 4 and 5 complements data supporting sediment deposition.

Nitrogen

Total nitrogen concentrations at the 2 most upstream sites appeared to peak on 17 May during the highest measured flows. Total nitrogen concentrations at site 4 were very low compared to other sites on that date, possibly due to an error in sampling or analyzing. Flows dropped by 28 May, and total nitrogen concentrations appeared to drop 10-50% from 17 May levels.

Figure 33 – Total Nitrogen Concentration at Upper Willow Creek Sites 1-5



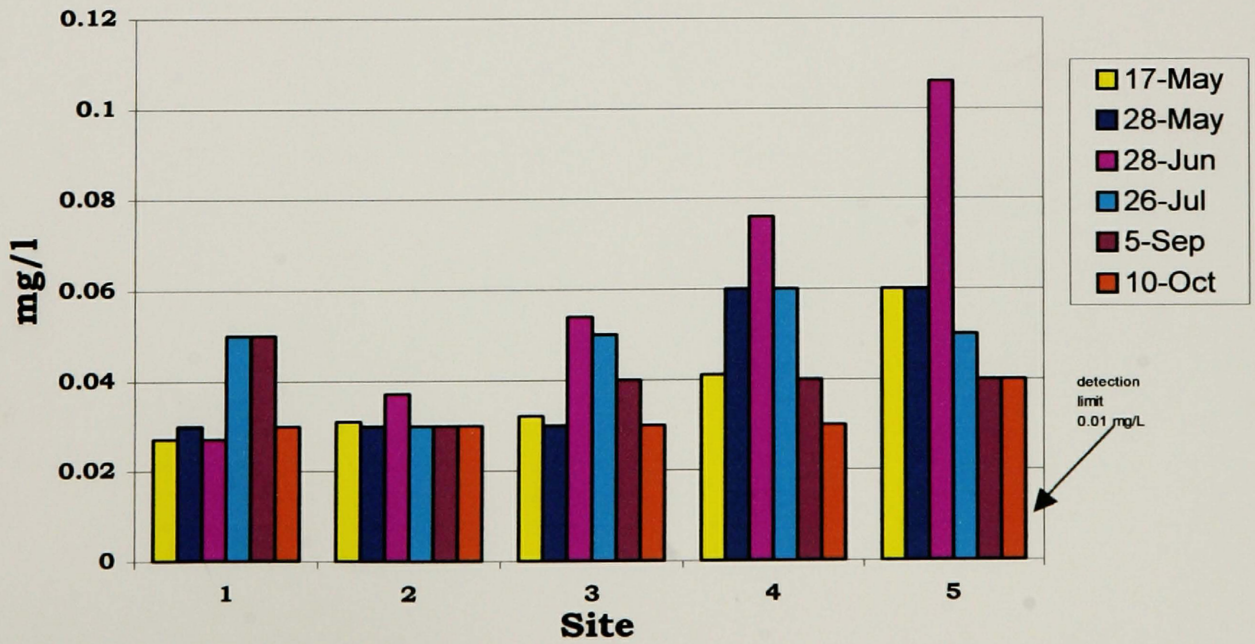
Although flows continued to recede through 28 June, total nitrogen concentrations measured higher at sites 3, 4 and 5, and were the highest recorded throughout the study. Application of fertilizers on private lands downstream of site 2 may explain the higher nitrogen concentrations during 28 June. Several landowners applied fertilizers during this period (Luthje 2001). The highest total nitrogen levels measured at sites 4 and 5 were 1.2 mg/l. Concentrations fluctuated between 0.2 and 0.4 mg/l at all sample sites throughout the remaining dates of 26 July, 5 September and 10 October. Total Kjeldahl nitrogen accounted for most of the total nitrogen. Dissolved nitrogen, in the form of NO_2 and NO_3 was near detection throughout the study. Of 30 nitrate samples, 25 were at or below detection levels (.01 mg/l) (Table 5). Overall, total nitrogen levels were high compared to state nutrient standards for the Clark Fork River. These standards set a target of 300 micrograms/liter (0.3 mg/l) concentration for total nitrogen. Of the 30 samples taken in Upper Willow Creek in 2001, 22 samples exceeded this standard.

Phosphorous

Samples taken during the highest recorded flows (17 May) showed a minimum total phosphorous concentration of 0.03 mg/l at site 1, and a maximum of 0.06 mg/l at site 5 (Figure 34). As the hydrograph fell through 28 May, concentrations appeared to remain in the same range of 0.03 to 0.06 mg/l.

Flows dropped slightly from 28 May to 28 June, however, total phosphorous concentrations appeared to increase at sites 3, 4 and 5. This pattern is similar to the nitrogen concentrations increasing at sites 3, 4 and 5 on 28 June, and may be due to fertilizer application. Phosphorous concentrations appeared to drop throughout the remainder of the study after 28 June and remained between 0.03 and 0.04 mg/l for all sites during base flows (10 cfs). Most of the TP was in the form of orthophosphates. This was determined by comparing the total phosphorous concentration with the orthophosphate concentrations.

Figure 34 – Total Phosphorous Concentration at Upper Willow Sites 1-5



Overall, Upper Willow Creek phosphorous levels were high relative to nutrient standards for the Clark Fork River (Administrative Rules of Montana 17.30.631). These standards set a target of 20 micrograms/liter (0.02 mg/l) total phosphorous from the headwaters of the Clark Fork River to the Blackfoot River confluence (standards apply from June 21st to September 21st). Of the 30 samples taken in Upper Willow Creek in 2001, all 30 exceeded this standard.

Soluble nitrogen/phosphorous ratios are shown in table 5. Ratios <5 suggest nitrogen-limited algal communities (Watson 2002). Nine of the 30 samples for the study period had soluble nitrogen (NO_2 and NO_3) levels above detection limits. Of these nine samples, all showed soluble nitrogen/phosphorous ratios of 1.0 or lower, indicating a nitrogen-limited system. During the R1-R4 habitat assessment, very little algae was noted throughout the entire length of Upper Willow Creek, likely due to the lack of soluble nitrogen.

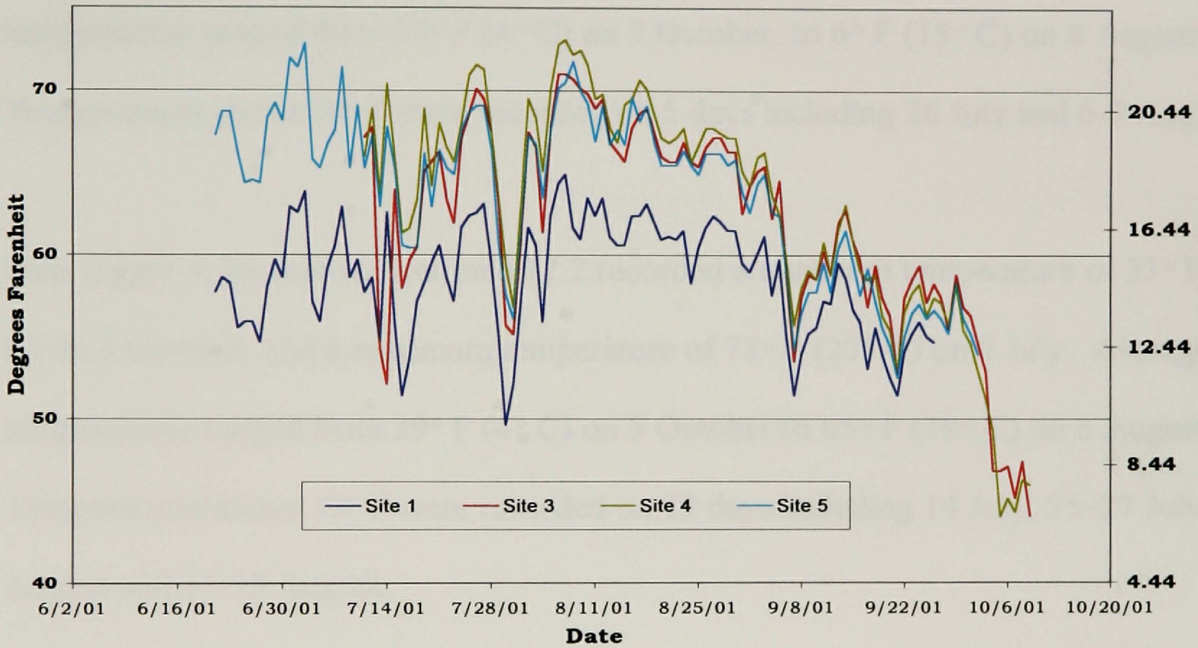
Table 5 – Total Nitrogen, Total Kjeldahl N, Nitrogen as NO_2 and NO_3, Ortho-Phosphate, Total Phosphorous and Soluble N/P Ratios in Upper Willow Creek, summer 2001.

Date	Site #	Nitrogen Total Kjel. (mg/l)	Nitrogen NO2, NO3 (mg/l)	Total Nitrogen (mg/l)	Ortho Phosphate (mg/l)	Total Phosphorous (mg/l)	Soluble N/P Ratio
5.17.01	1	0.5	<0.01	0.51	0.019	0.027	N/A
	2	0.7	0.02	0.72	0.026	0.031	0.8
	3	0.8	0.02	0.82	0.02	0.032	1.0
	4	<0.1	0.02	<0.05	0.025	0.041	0.8
	5	0.8	0.02	0.82	0.04	0.06	0.5
5.28.01	1	0.4	<0.01	0.41	0.03	0.03	N/A
	2	0.4	<0.01	0.41	0.03	0.03	N/A
	3	0.4	<0.01	0.41	0.03	0.03	N/A
	4	0.6	<0.01	0.61	0.04	0.06	N/A
	5	0.7	<0.01	0.71	0.05	0.06	N/A
6.28.01	1	0.3	0.01	0.31	0.03	0.027	0.3
	2	0.5	0.01	0.51	0.03	0.037	0.3
	3	1.1	0.01	1.11	0.03	0.054	0.3
	4	1.2	0.01	1.21	0.05	0.076	0.2
	5	1.2	<0.01	1.21	0.07	0.106	N/A
7.26.01	1	0.2	<0.01	0.21	0.04	0.05	N/A
	2	0.2	<0.01	0.21	0.03	0.03	N/A
	3	0.3	<0.01	0.31	0.04	0.05	N/A
	4	0.4	<0.01	0.41	0.05	0.06	N/A
	5	0.3	<0.01	0.31	0.05	0.05	N/A
9.05.01	1	0.2	<0.01	0.21	0.04	0.05	N/A
	2	0.2	<0.01	0.21	0.04	0.03	N/A
	3	0.2	<0.01	0.21	0.04	0.04	N/A
	4	0.3	<0.01	0.31	0.04	0.04	N/A
	5	0.3	<0.01	0.31	0.05	0.04	N/A
10.10.01	1	0.2	0.02	0.22	0.03	0.03	0.7
	2	0.4	<0.01	0.41	0.03	0.03	N/A
	3	0.3	<0.01	0.31	0.03	0.03	N/A
	4	0.2	<0.01	0.21	0.03	0.03	N/A
	5	0.3	<0.01	0.31	0.03	0.04	N/A

Temperature

Maximum daily temperatures were recorded at sample sites 1-5 to note the frequency of periods during which the water exceeded 70° F (21° C). Five data loggers recorded maximum water temperatures every 1.5 hours (Figure 35).

Figure 35 – Maximum Temperatures at Upper Willow Creek Sites 1, 3, 4 and 5



Loggers 1 and 5 were active from 21 June to 2 October. Loggers 3 and 4 were active from 11 July to 9 October.

Data logger 1, located at river mile 0, recorded a minimum temperature of 38° F (3° C) on 20 September, and a maximum temperature of 65° F (18° C) on August 7th. Average daily temperatures ranged from 45° F (7° C) on 20 September to 56° F (13° C) on 7 August. At no time were temperatures recorded above 70° F at this site.

Data logger 2 was not recovered because a beaver dam was constructed on top of the logger.

Data logger 3, located at river mile 11.5 recorded a minimum temperature of 33° F (1° C) on 6 October, and a maximum temperature of 71° F (22° C) on 7 August. Average daily temperatures ranged from 39° F (4° C) on 5 October, to 6° F (15° C) on 8 August. Temperatures above 70° F were recorded on 5 days including 26 July and 6-9 August.

Data logger 4, located at river mile 17.2 recorded a minimum temperature of 33° F (<1° C) on 3 October, and a maximum temperature of 73° F (23° C) on 7 July. Average daily temperatures ranged from 39° F (4° C) on 5 October to 65° F (19° C) on 8 August. Temperatures above 70° F were recorded on 12 days including 14 July, 25–27 July, 5-10 August and 17-18 August.

Data logger 5, located at river mile 21.0 recorded a minimum temperature of 43° F (6° C) on 1 October, and a maximum temperature of 72° F (23° C) on 3 July. Average daily temperatures ranged from 49° F (9° C) on 21 September to 65° F (18° C) on 8 August. Temperatures exceeding 70° F were recorded on 7 days including 1-3 July, 8 July, and 6-8 August.

Discussion and Conclusions

Physical, chemical, and biological conditions vary along the length of Upper Willow Creek. In-stream habitat, riparian function, channel stability and fisheries populations in upstream Section I (stream mile 0.0 to stream mile 9.5) are in good condition. Within this section, Upper Willow Creek supports fisheries and aquatic life, two of its impaired beneficial uses as determined by the Montana Department of Environmental Quality. Section II (stream mile 9.5 to stream mile 15.7) shows numerous habitat and channel alterations, resulting in poor riparian and instream conditions, limited fisheries habitat and high sediment inputs. Section III (stream mile 15.7 to stream mile 21.3) shows fair conditions, but some problems exist. Channel stability and riparian function showed improved condition in Section III relative to Section II; however, substrate composition and water quality are compromised by upstream disturbances.

Causes of Impairment

A primary factor preventing Sections II and III of Upper Willow Creek from fully supporting aquatic life and cold-water fisheries is the extent to which the creek has been channelized. Significant areas of the creek show high, artificially built banks, straightened meanders and fill placed in historic channels to increase hay production and prevent flood flows from reaching agricultural land. Most of the artificial banks have poor vegetation quality and low bank stabilizing root mass. Channelized reaches do not allow the creek to access its natural floodplain, forcing the stream's energy during high flow events onto unvegetated and unstable banks. Channelization decreases stream length while increasing channel gradient, resulting in higher water velocities and additional erosive forces on the channel bed. As a result, the creek shows several stages of vertical erosion, or downcutting in R1-R4 reaches 5-9. This downcutting is indicated by tributary headcuts and entrenched channels.

Upper Willow Creek in Section I is primarily a Rosgen C4 channel dominated in several areas by beaver dams. The historic condition in Section II was likely a combination of E4 and C4 channels. However, anthropomorphic alterations and associated lateral and vertical instability have resulted in the channel changing to an F4 in multiple locations. The "E" type stream is characterized by low gradient (<2%), low width/depth ratio (<12), high sinuosity (>1.5) and high pool density as a result of short riffles between meander scours (Rosgen 1996). These streams are considered very stable, but very sensitive to disturbance and can be rapidly adjusted and converted to other stream types (Rosgen 1996; Brooks et al. 1997). The "C" stream type is characterized by low gradient (<2%), meandering, point-bar, riffle/pool and alluvial channels with broad, well defined floodplains (Rosgen 1996). Usually, width/depth ratios are exceed 12 and sinuosity is 1.2 or higher (Rosgen 1996). Aerial photos of Upper Willow Creek reveal historic meander channel patterns with higher sinuosity in areas now converted to relatively straight, confined reaches. This confinement of the historic floodplain has resulted in the stream attempting to reestablish a new floodplain by eroding both vertically and laterally. This activity has led to several reaches exhibiting "F" channel characteristics.

Streams exhibiting "F" characteristics often result from the lack of a functional floodplain (Rosgen 1996; Brooks et al. 1997). F-type channels can develop high bank erosion rates, high lateral extension rates, significant bar deposition and accelerated channel aggradation and/or degradation while providing for very high sediment supply and storage capacity (Rosgen 1996). In the case of Upper Willow Creek, the floodplain has been made inaccessible in multiple reaches. Without regular access to a floodplain, the energy of the creek within channelized areas will first displace channel substrate vertically and then begin to reshape a new floodplain at a lower elevation to provide meander capability. Upper Willow Creek shows all of these characteristics in Section II, including poor bank stability and excessive lateral erosion in areas of unhealthy riparian vegetation. Within areas severely altered by channel constriction, the creek shows many instances of its ability to reform back to a C or E-type channel. R1-R4 reach 6 has long sections of straightened channel (sinuosity = 1.0 in some areas). Meandering is beginning to occur as the channel reshapes to a more stable, sinuous pattern in some areas. In areas where the creek is beginning to establish a more natural pattern of sinuosity, lateral scouring has created deep pools. Although these pools provide refuge for fish, the low pool densities in these areas, combined with high sediment transport in eroding areas, creates the capacity for substrates dominated by fine sediments. High amounts of fine sediment deposition decrease macroinvertebrate production and salmonid spawning success.

This process of channel evolution from an F to a more natural and stable C or E-type erodes large amounts of sediment not only within the downcutting creek, but also in tributaries associated with that reach. Once the mainstem stabilizes by the process described, the bed elevation can lower significantly, causing entering tributaries to headcut in an attempt to connect with a lower confluence elevation. The hydrologic process of a channel changing from an artificially chanelized reach to a newly established floodplain and stable meander pattern can take several hundred flood cycles and may contribute excessive sediment inputs during the recovery period. Because Section III exhibits a more natural, sinuous channel pattern, pool density increases and water velocities are slower than in Section II. As a result, sediment inputs from Section II are depositing throughout Section III. This sediment transport pattern is supported by decreases in total suspended sediment load during higher flows and higher percentages of fine particles found in R1-R4 reaches 7, 8 and 9. High sediment deposition in the form of fine substrates degrades salmonid spawning conditions and benthic macroinvertebrate populations (Weaver and White 1985; Rothrock et al. 1998). Fine particles impede movement of water through the gravel, thereby reducing delivery of dissolved oxygen and flushing of metabolic wastes away from incubating salmonid embryos (MBTSG 1998; Everest et al. 1987). Fine sediments accumulating in Section III deteriorate salmonid spawning and macroinvertebrate habitat.

Altered channel reaches in Section II also showed unhealthy riparian vegetation. The low percentage of woody vegetation in reaches 5, 6 and 7 provides little overhanging cover or thermal protection for fish. Migratory trout may enter spawning streams and arrive at spawning areas weeks or months before they actually spawn (MBTSG 1998; Leggett 1969; Fraley and Shepard 1989; Carnefix 2002) and can be vulnerable to disturbance or predation if holding areas have little or no cover. The low pool density throughout Section II provides limited habitat for feeding and resting fish, and the lack of thermal cover assists in elevating surface water temperatures to undesirable levels. Temperatures exceeding 70 degrees interfere with salmonid enzymatic and immune system function and reproductive capability. In addition, dissolved oxygen levels are stressfully low above this temperature (Reiland 2002). Temperatures exceeded 70 degrees F (21° C) at sample sites 3, 4 and 5 revealing further unfavorable conditions for fish populations.

Fish population estimates suggest trout populations in reaches below sample transect 3 are depressed relative to upstream sites. Factors limiting salmonid populations include combinations of poor spawning habitat, absence of protective overhanging cover, low pool densities and high temperatures. Data for maximum temperature and pool substrates in lower reaches show less than optimal conditions for salmonid use in Section II and III of Upper Willow Creek.

Because nitrogen and phosphorous levels recorded for this study often exceeded standards set by the Administrative Rules of Montana for the Clark Fork River, one could argue for the need for restoration to reduce excessive nutrient loads. Most nutrient loading is probably associated with poor riparian buffer zones in fertilized areas, concentrated livestock in the riparian zone, and on-stream corrals. All water samples exceeded the total phosphorous standards for the Upper Clark Fork of 20 mg/l for the Upper Clark Fork, and 43% of the samples exceeded the total phosphorous standard for the Middle Clark Fork. Total suspended sediment samples were below detection levels except during the highest recorded flows. It is important to note this study was conducted during a very dry year. Annual precipitation levels in 2001 were approximately 63% of average. Upper Willow Creek will produce higher sediment loads during average and above average flow conditions if current conditions remain.

Restoration Benefits

Current conditions of several Upper Willow Creek reaches limit the ability of the creek to provide high quality riparian function and in-stream benefits. Although it is not feasible to restore Upper Willow Creek to a historic, pre-settlement condition, certain restoration techniques paired with grazing management could provide the creek long-term stability, effective sediment transport, in-stream habitat and healthy riparian vegetation. Revegetation of overgrazed reaches would decrease sediment inputs by protecting unstable banks. Upper Willow Creek has been identified as the warmest tributary in the upper Rock Creek basin (Carnefix 2002). Increasing woody composition along reaches subject to chemical and physical removal of riparian vegetation would provide a shading canopy, essential for thermal protection. A revegetation effort will benefit fisheries by providing cover from predators and decreasing daily maximum temperatures currently exceeding 70° F in lower reaches of Upper Willow Creek. Cooling water temperatures would help slow aquatic infection rates in both Upper Willow Creek and Rock Creek basins. The whirling disease-carrying *Tubifex tubifex* worm is known to flourish in warm water mud deposits (El-Matbouli et al. 1999). Elevated water temperature has been shown to increase the virulence and maturation rate of *Myxobolus cerebralis*, the whirling disease parasite (Schisler and Bergersen 2000). Addition of a riparian buffer in severely denuded areas would assist in decreasing nutrient inputs, especially in reaches heavily utilized by cattle. Channel and floodplain reconstruction in channelized reaches can increase sinuosity, pool density, bank stability to a more naturally stable pattern and profile. Reduction of large sediment inputs would reduce fine sediment deposition downstream, enhancing salmonid spawning conditions and macroinvertebrate production.

Consulting firms specializing in stream restoration often utilize "reference reaches" to base morphological designs. Potential reference reaches identified by this study include the BLM-managed parcel (R1-R4 reach 6, RWRP polygon H), a reach below Scotchman's Bridge (R1-R4 reach 8, RWRP polygon O), and just upstream of the confluence of Rock Creek (R1-R4 reach 10, polygon R). Polygon H lies directly upstream of a proposed restoration reach (Reach 6), showed excellent in-stream habitat conditions and achieved the highest RWRP rating for polygons in Sections II and III. Valley width, slope and substrate composition are more similar to the proposed restoration reach in polygons O and R than polygon H. The channel in polygon H is confined to a narrow gully between two wide meadows and has a coniferous, rather than willow-dominated, habitat type. The RWRP survey of polygon O indicated a functional riparian area, and achieved a higher score than any polygon in Section III. Polygon R exhibits high bank stability, fair riparian vegetation composition and natural channel characteristics (Rosgen E-type) and are likely similar to historic conditions in the proposed restoration reach.

Although reach 6 illustrated the worst is-stream habitat, bank and riparian health conditions throughout Upper Willow Creek, this study shows water quality and both riparian and aquatic habitat conditions could be enhanced in additional areas. Previous stream restoration projects suggest channel reconstruction and revegetation should begin upstream and work in a downstream direction. Hence, it would be logical to begin restoration efforts in the area defined in this study as R1-R4 reach 5. This reach lies upstream of the proposed restoration project area and also shows extensive riparian and hydrologic problems. Restoration within this reach would reduce sediment inputs to the creek, providing additional benefits to aquatic resources. R1-R4 reach 7 shows a similar condition, and would greatly improve the quality of Upper Willow Creek if adequately restored. Landowner participation is sometimes challenging, yet essential in establishing a restoration plan on private land. Fortunately, there are benefits associated with restoration projects such as the Natural Resource and Conservation Service's (NRCS) Conservation Reserve Program offering compensation to landowners for agricultural land lost due to habitat enhancement.

Recommendations

This study documents baseline biological, physical and chemical conditions of Upper Willow Creek prior to restoration work to improve fisheries habitat, water quality and vegetation health. If active restoration work is initiated, this study could serve as a comparison to future conditions if similar parameters are investigated. Revegetation efforts should be monitored to determine survival rates, effectiveness of stabilizing banks, and availability of thermal protection. Fish populations should also be monitored to document trends in populations after any restoration is completed.

Although a proposed restoration project in Reach 6 will enhance riparian vegetation and fish populations while decreasing sediment and nutrient loads, this project would be complimented by additional restoration in other reaches of Upper Willow Creek. Riparian fencing would discourage degradation of existing vegetation in Section III and prevent similar problems associated with poor bank stability and sediment inputs. Headgates and bridges throughout Section II and III could be redesigned to reduce the probability of failure. The NRCS could work with landowners to change from current irrigation methods to center-pivot systems. This would reduce excessive water removal from the creek and prevent trapped fish in irrigation ditches. Off-site stock water systems would reduce hoof shear and collapsed banks in grazed areas while protecting riparian vegetation. This could be especially beneficial in reducing nutrient inputs due to winter corrals if fencing removes livestock from riparian zones.

Upper Willow Creek is an example of a lotic system influenced by multiple uses throughout the drainage. Effects of alterations in channel morphology and riparian vegetation throughout numerous reaches degrade the quality of aquatic habitat and fisheries value. Although channel and vegetation modifications in lower reaches of Upper Willow Creek appear minimal, these areas exhibit degraded instream habitat quality due to several disturbances originating in mid-reaches. Appropriate restoration and management of the stream and riparian zone should increase the functional capability of Upper Willow Creek to support several beneficial uses including agriculture, livestock, aquatic life, fisheries and recreation.

Appendix A – Lotic Health Assessment Field Score Sheet

LOTIC HEALTH ASSESSMENT
FIELD SCORE SHEET

1. Vegetative Cover of Floodplain and Streambanks. Score: -
   - 6 = More than 95% of the reach soil surface is covered by plant growth.
   - 4 = 85% to 95% of the reach soil surface is covered by plant growth.
   - 2 = 75% to 85% of the reach soil surface is covered by plant growth.
   - 0 = Less than 75% of the reach soil surface is covered by plant growth.

2. Invasive Plant Species. Score: -
   - 6 = No invasive species on the site.
   - 4 = Less than 1 % of site infested by invasive species.
   - 2 = 1 % to 15% of site infested by invasive species.
   - 0 = More than 15% of site infested by invasive species.

3. Disturbance-increaser Undesirable Herbaceous Species. Score: -
   - 3 = Less than 5% of the site covered by disturbance-increaser undesirable herbaceous species.
   - 2 = 5% to 25% of the site covered by disturbance- increaser undesirable herbaceous species.
   - 1 = 25% to 45% of the site covered by disturbance-increaser undesirable herbaceous species.
   - 0 = More than 45% of the site covered by disturbance-increaser undesirable herbaceous species.

4. Preferred Tree and Shrub Establishment and Regeneration. Score: -
   - 6 = More than 15% of the total canopy cover of preferred trees/shrubs is seedlings and saplings.
   - 4 = 5% to 15% of the total canopy cover of preferred trees/shrubs is seedlings and saplings.
   - 2 = Less than 5% of the total canopy cover of preferred tree/shrubs is seedlings and saplings.
   - 0 = Preferred tree/shrub seedlings or saplings absent.

5. Utilization of Preferred Trees and Shrubs. Score:
   - 3 = None (0% to 5% of available second year and older leaders of preferred species are browsed).
   - 2 = Light (5% to 25% of available second year and older leaders of preferred species are browsed).
   - 1 = Moderate (25% to 50% of available second year and older leaders of preferred species are browsed).
   - 0 = Heavy (More than 50% of available second year and older leaders of preferred species are browsed).

6. Standing Decadent and Dead Woody Material. Score: -
   - 3 = Less than 5% of the total canopy cover of woody species is decadent or dead.
   - 2 = 5% to 25% of the total canopy cover of woody species is decadent or dead.
   - 1= 25% to 45% of the total canopy cover of woody species is decadent or dead.
   - 0 = More than 45% of the total canopy cover of woody species is decadent or dead.

7. Streambank Root Mass Protection. Score:_
   - 6 = More than 85% of the streambank has a deep, binding root mass.
   - 4 = 65% to 85% of the streambank has a deep, binding root mass.
   - 2 = 35% to 65% of the streambank has a deep, binding root mass.
   - 0 = Less than 35% of the streambank has a deep, binding root mass.

8. Human-Caused Bare Ground. Score: -
   - 6 = Less than I % of the site is human-caused bare ground.
   - 4 = 1 % to 5% of the site is human-caused bare ground.
   - 2 = 5% to 15% of the site is human-caused bare ground.
   - 0 = More than 15% of the site is human-caused bare ground.

9. Streambank Structurally Altered by Human Activity. Score:
   - 6 = Less than 5% of the bank is structurally altered by human activity.
   - 4 = 5% to 15% of the bank is structurally altered by human activity.
   - 2 = 15% to 35% of the bank is structurally altered by human activity.
   - 0 = More than 35% of the bank is structurally altered by human activity.

10. Pugging and/or hummocking. Score:

3 = Less than 5% of the polygon is affected by pugging and/or hummocking.

2 = 5% to 15% of the polygon is affected by pugging and/or hummocking.

1 = 15% to 25% of the polygon is affected by pugging and/or hummocking.

0 = More than 25% of the polygon is affected by pugging and/or hummocking.

11. Stream Channel Incisement (vertical stability). Score:

9= Channel vertically stable and not incised; 1-2 year high flows access a floodplain appropriate to the stream type. Active downcutting is not evident. Any old incisement is characterized by a broad floodplain inside which perennial riparian plant communities are well established. (Stages A-1, A-2, or A-3 of Figure 3.)

6 = Either of two incisement phases: (a) an early phase where the channel is just beginning to downcut. May be small headcuts, but bankfull flows still access the floodplain. (Look for cutting in channel bottoms) or (b) an old incisement in which the channel may still show limited active downcutting. A new floodplain is well formed at the lower level, although much narrower than it may become. Lateral bank cutting is likely still widening the incised system on outside curves. Perennial riparian plants are becoming well established. (Stage B of Figure 3.)

3 = Two phases of incisement also fit this rating. (a) an intermediate phase with downcutting and headcuts probable. Channel is not yet so deeply incised that medium (5-10 year) high flows cannot escape the banks or (b) a deep incisement that is starting to heal. In this phase new floodplain development, though very limited, is key. (Look for widening of the incised system and for early establishment of pioneer perennial plants on the new depositional surfaces.) (Stage C of Figure 3.)

0 = The channel is deeply incised to resemble a ditch or a gully. Downcutting is likely ongoing. Only extreme floods overtop the banks. No floodplain development has begun. (Stages D-1 or D•2 of Figure 3.)

Appendix B – RWRP Polygon Scores by Category, Total Scores and Functional Rating

	Lotic Health Inventory Category													
Polygon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**Total**	**Score**	**Rating**
PtsPoss	6	6	3	6	3	3	6	6	6	3	9	57	100	
A	6	4	2	6	2	3	6	4	6	3	9	51	89	Functional
B	6	6	3	4	2	3	6	4	6	3	9	52	91	Functional
C	6	4	3	4	2	3	6	4	6	2	9	49	86	Functional
D	6	4	2	6	2	3	4	6	4	2	9	48	84	Functional
E	4	4	2	2	1	2	2	2	4	2	6	31	54	Non-Functional
F	6	4	2	4	2	3	4	6	2	2	9	44	77	Functional-at-Risk
G	4	4	2	2	1	1	0	4	2	2	9	31	54	Non-Functional
H	6	4	3	6	1	2	4	6	6	3	9	50	88	Functional
I	2	4	2	2	0	0	0	2	0	2	0	29	51	Non-Functional
J	2	4	2	2	1	1	0	2	0	2	0	25	44	Non-Functional
K	4	4	3	2	0	2	0	2	0	3	0	23	40	Non-Functional
L	2	4	3	0	0	2	0	2	2	2	9	26	46	Non-Functional
M	4	4	3	0	1	1	0	4	2	2	9	30	53	Non-Functional
N	4	4	2	2	0	1	0	2	4	1	9	29	51	Non-Functional
O	6	4	2	4	2	2	4	6	6	2	9	47	82	Functional
P	4	4	3	2	1	2	4	4	2	2	6	34	60	Non-Functional
Q	6	4	3	2	1	2	4	4	4	3	9	42	74	Functional-at-Risk
R	6	4	3	2	1	2	2	6	6	2	6	40	70	Functional-at-Risk

Category	**Description**
1	Vegetative Cover of Floodplain and Streambanks
2	Invasive Plant Species
3	Disturbance-Increaser Undesirable Herbaceous Species
4	Preferred Tree and Shrub Establishment and Regeneration
5	Utilization of Preferred Trees and Shrubs
6	Standing Decadent and Dead Woody Material
7	Streambank Root Mass Protection
8	Human-Caused Bare Ground
9	Streambank Structurally Altered by Human Activity
10	Pugging and/or Hummocking
11	Stream Channel Incisement (vertical stability)

Appendix C – R1-R4 In-stream Habitat Inventory Field Form – Page 1

Stream: ______________________ Basin: __________ Observers: ______________

Date: ______ Legal: T. ______ R. ______ Sects. ______ Survey Direction: __________

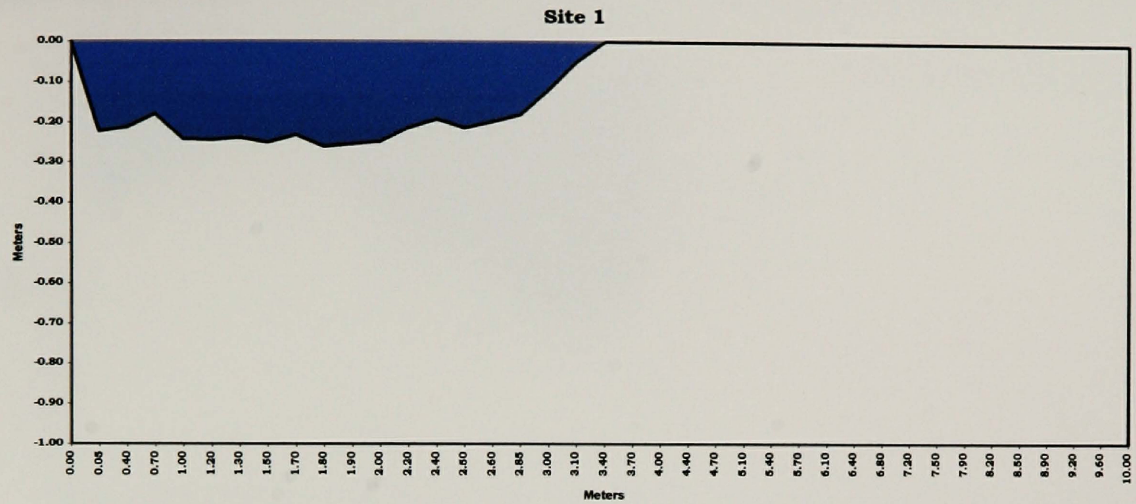
Upper Boundary: ______________________ Lower Boundry: ______________

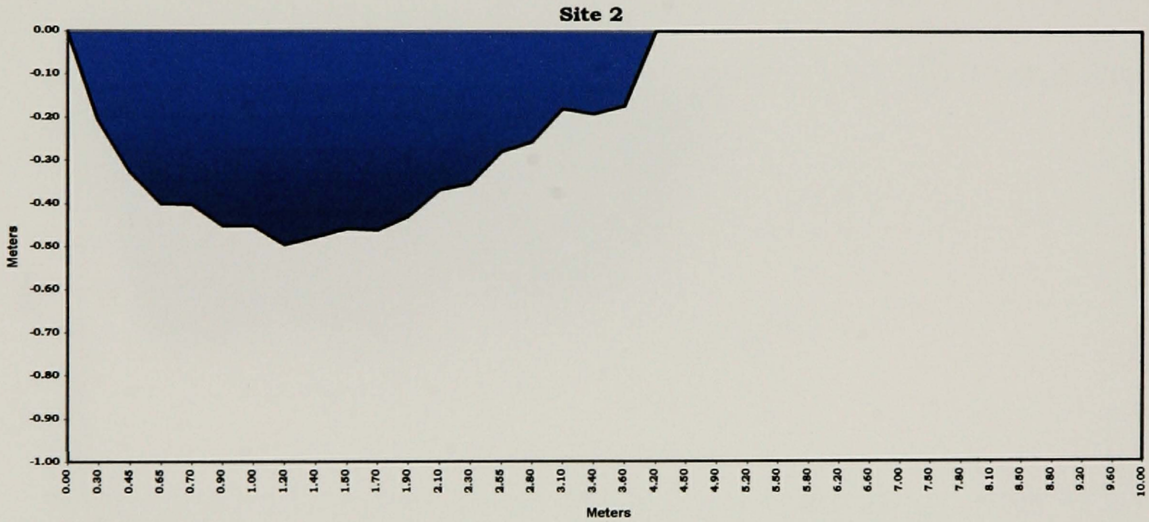
Hab. Unit	Tape Length	Unit Length	Habitat Type Basic	Detailed	Bank Stability % L	Bank Stability % R	LWD #	Bank Vegetaion % Woody	Herb.	Regen.	Additional Information
1		0									
2		0									
3		0									
4		0									
5		0									
6		0									
7		0									
8		0									
9		0									
10		0									
11		0									
12		0									
13		0									
14		0									
15		0									
16		0									
17		0									
18		0									
19		0									
20		0									

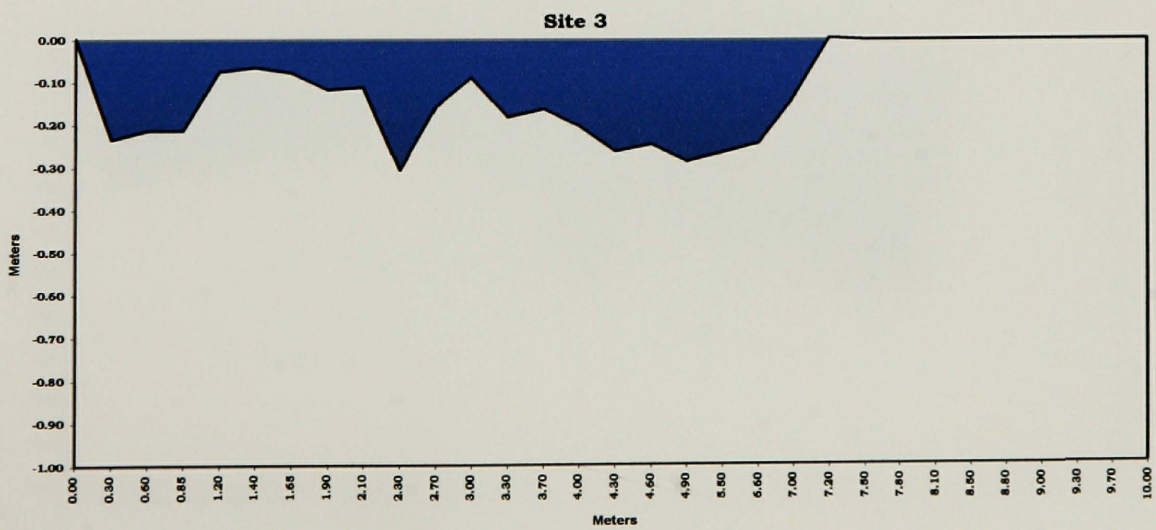
Appendix C Continued – R1-R4 In-stream Habitat Inventory Field Form – Page 2

Width		Depth		Undercut Banks %		Comments
Bank	Wet	P-max	F-avg. max	L	R	

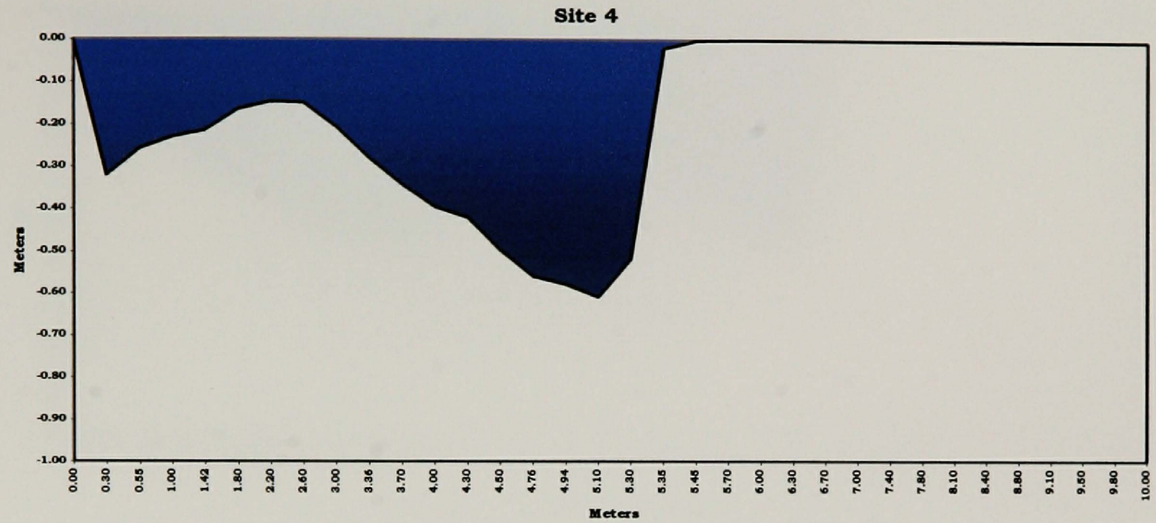
Appendix D – Upper Willow Creek Channel Cross Sections at Sites 1-10

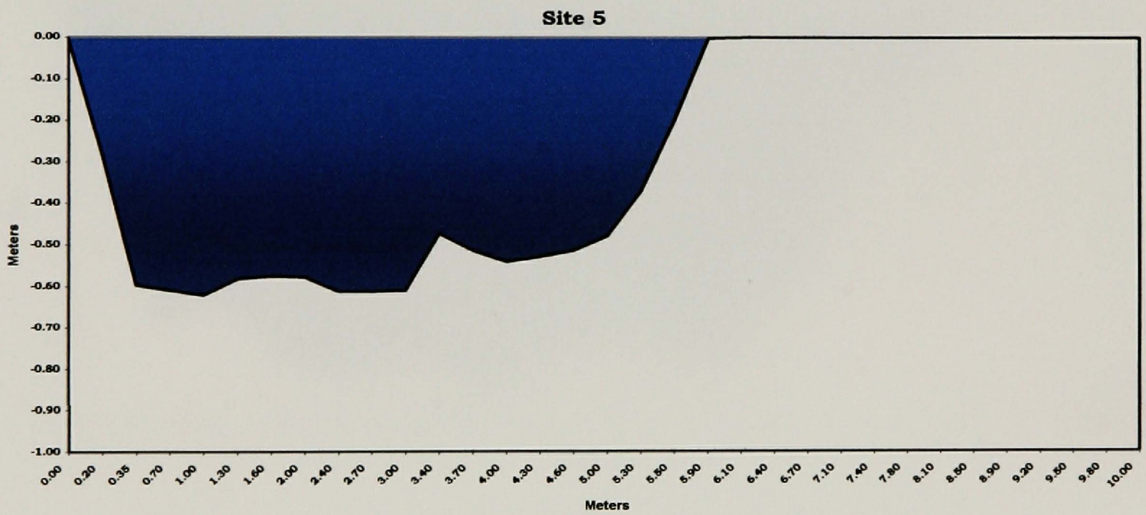


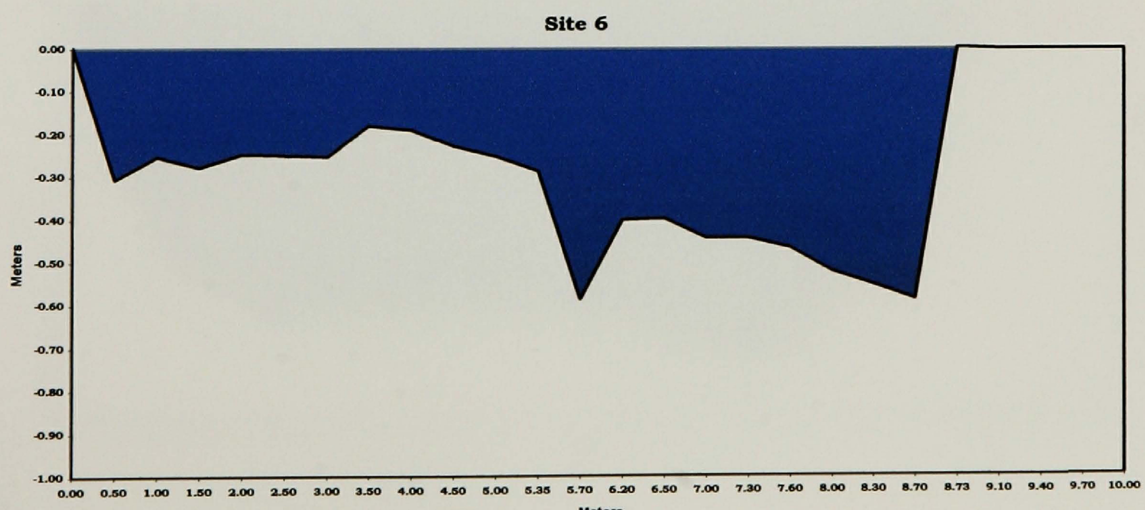




Appendix D Continued – Upper Willow Creek Channel Cross Sections 1-10

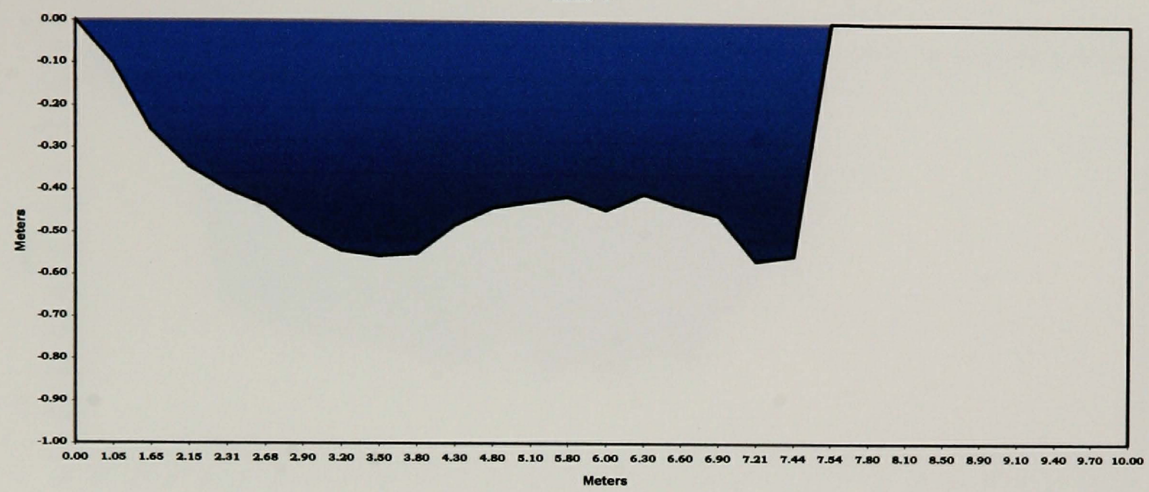




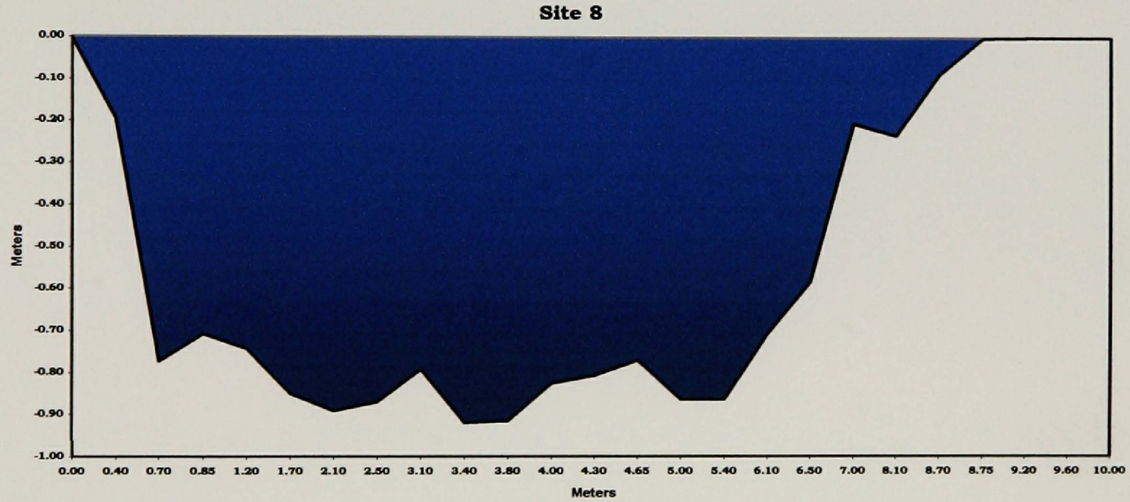


Appendix D Continued – Upper Willow Creek Channel Cross Sections 1-10

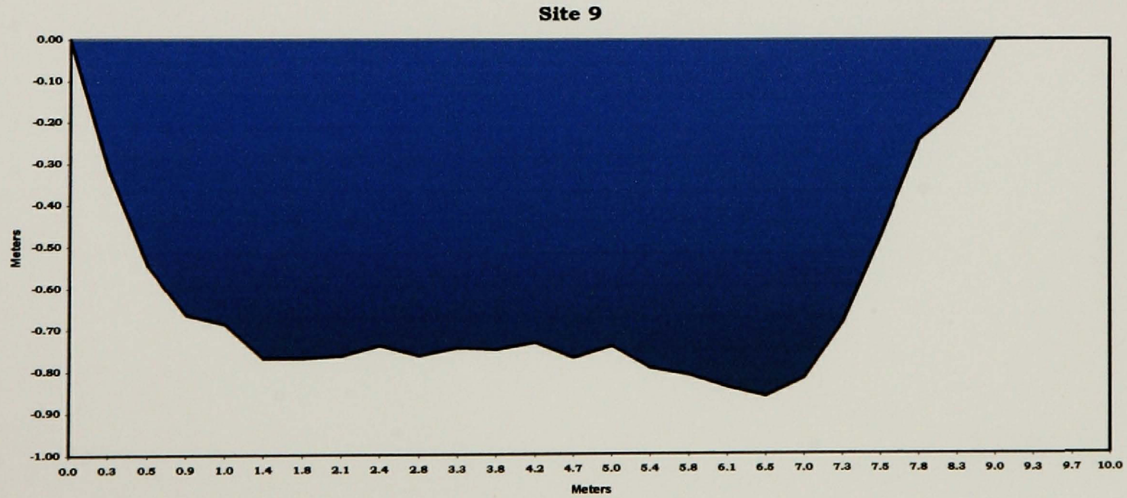
Site 7



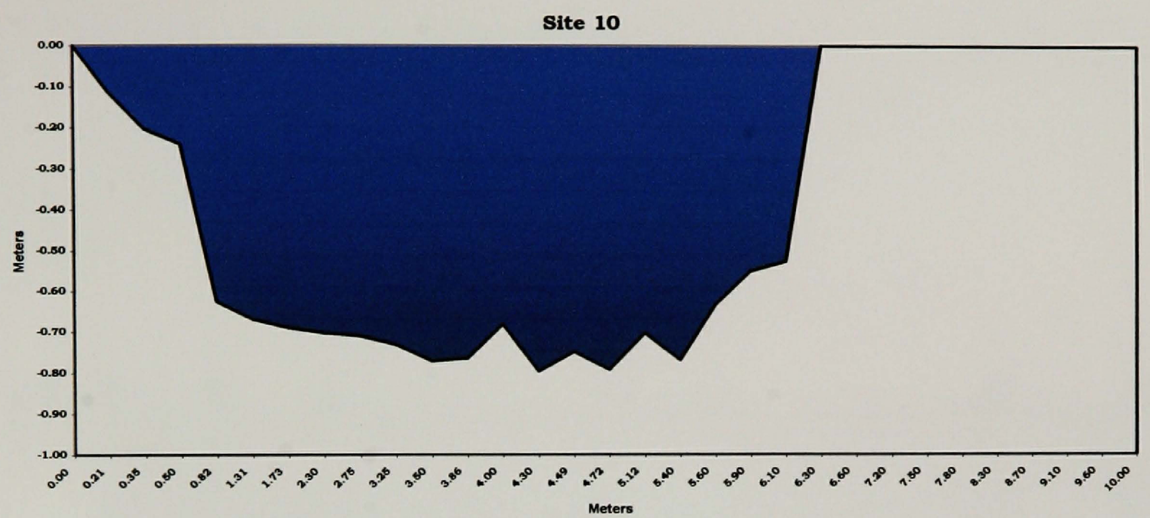
Site 8



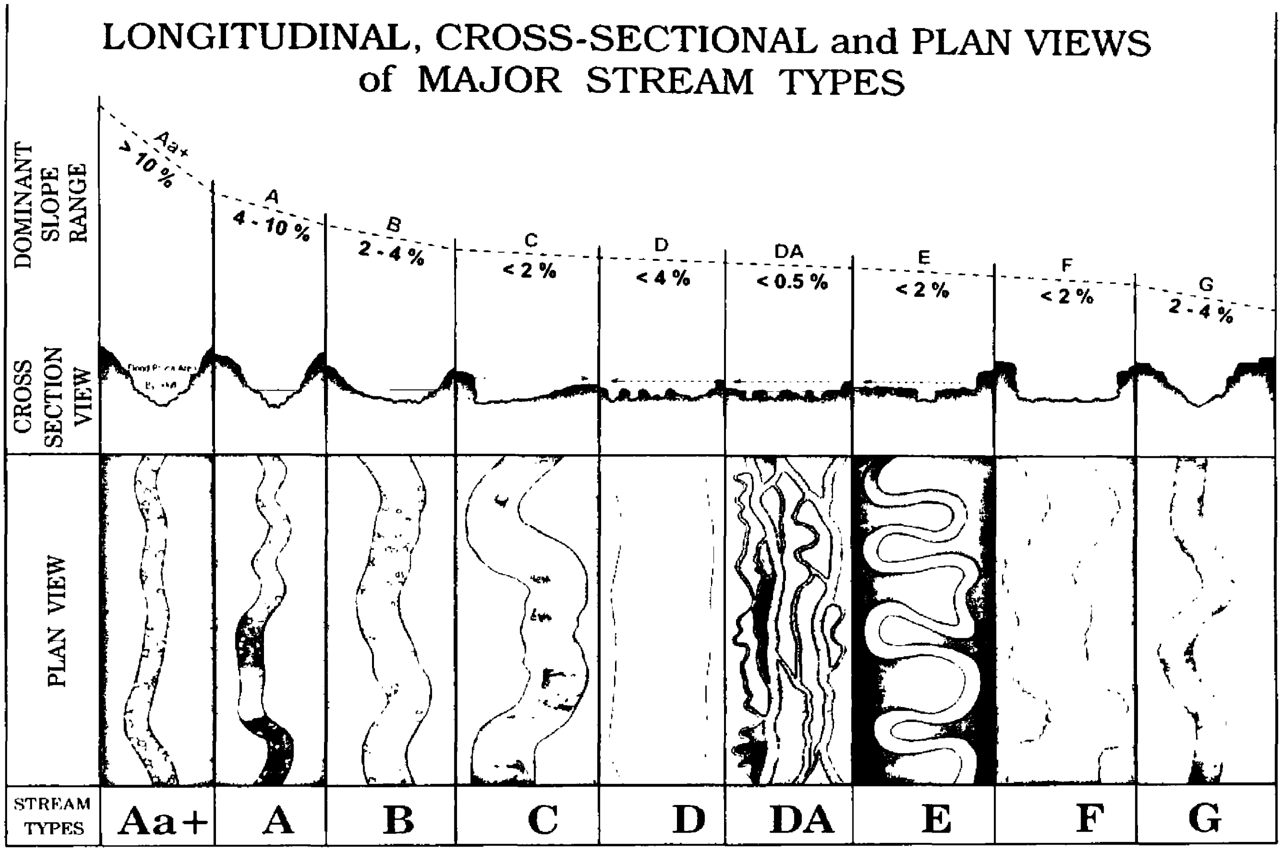
Site 9



Appendix D Cont. – Upper Willow Creek Channel Cross Sections 1-10



Appendix E – Rosgen Stream Classification (from Rosgen 1996)



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